ASTRONOMY

November 1984
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Video Astronomy, Part 1

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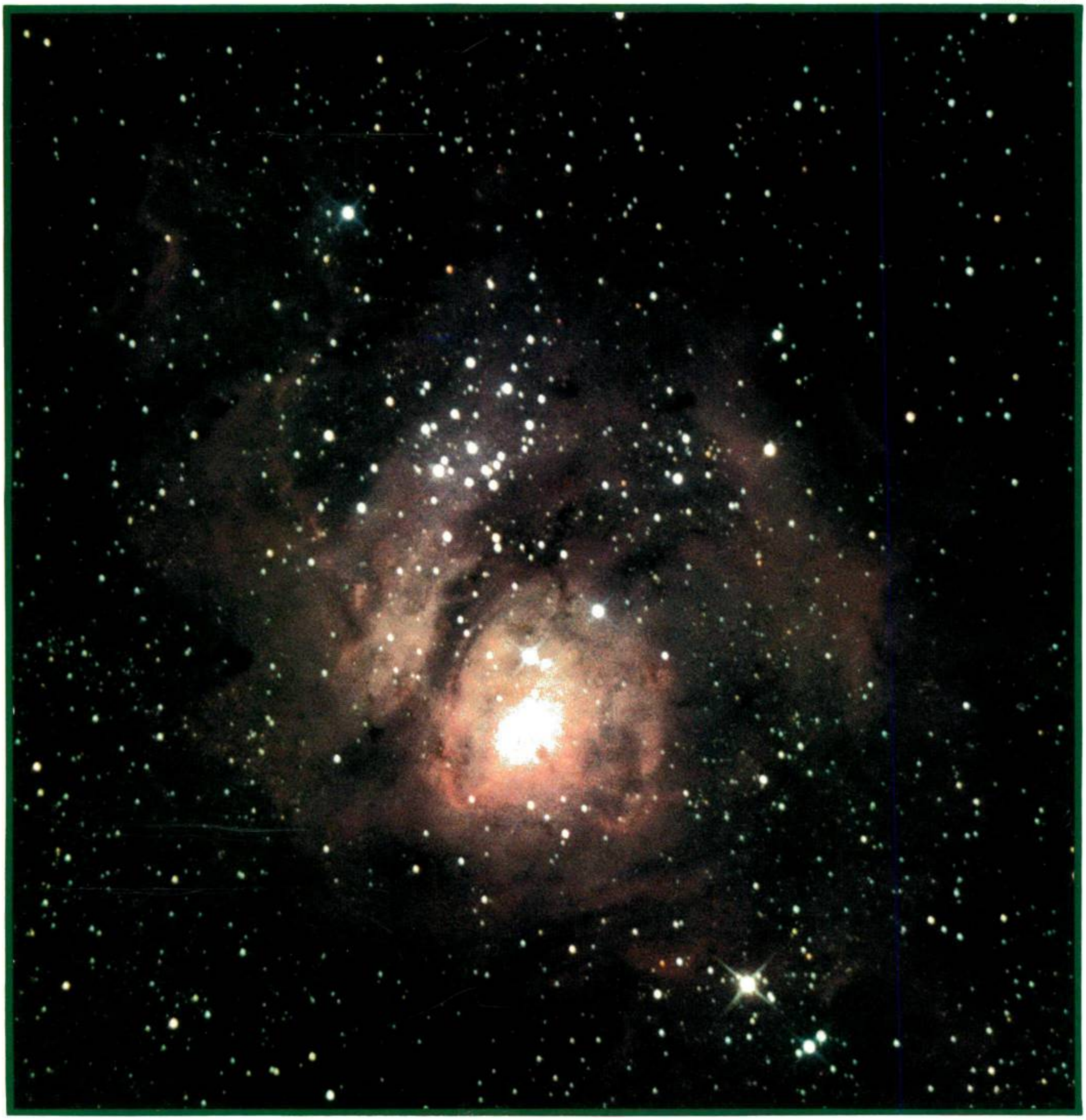
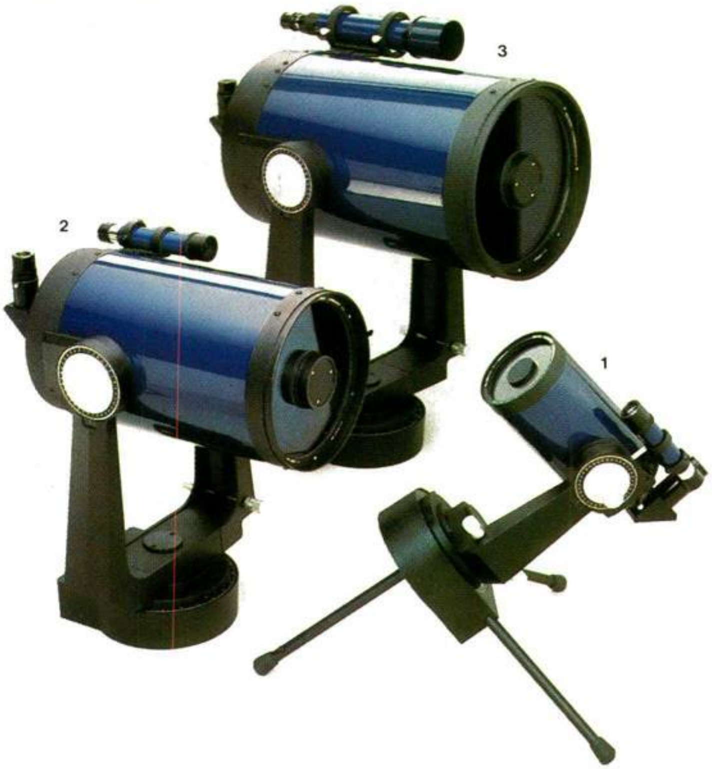


Emission Nebula M-8 in Sagittarius



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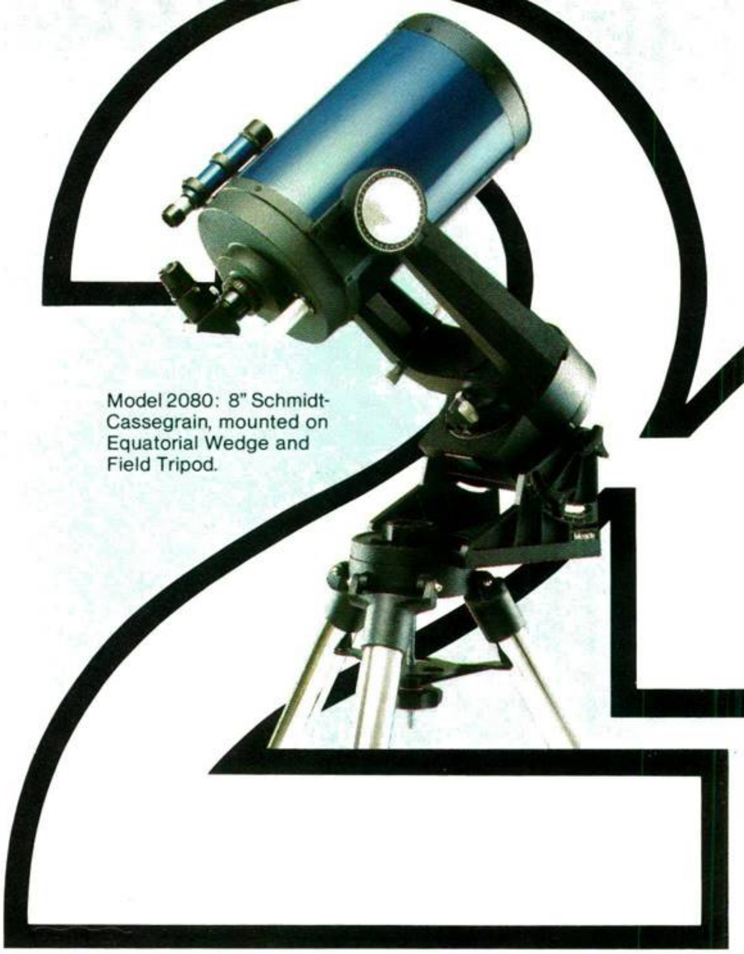

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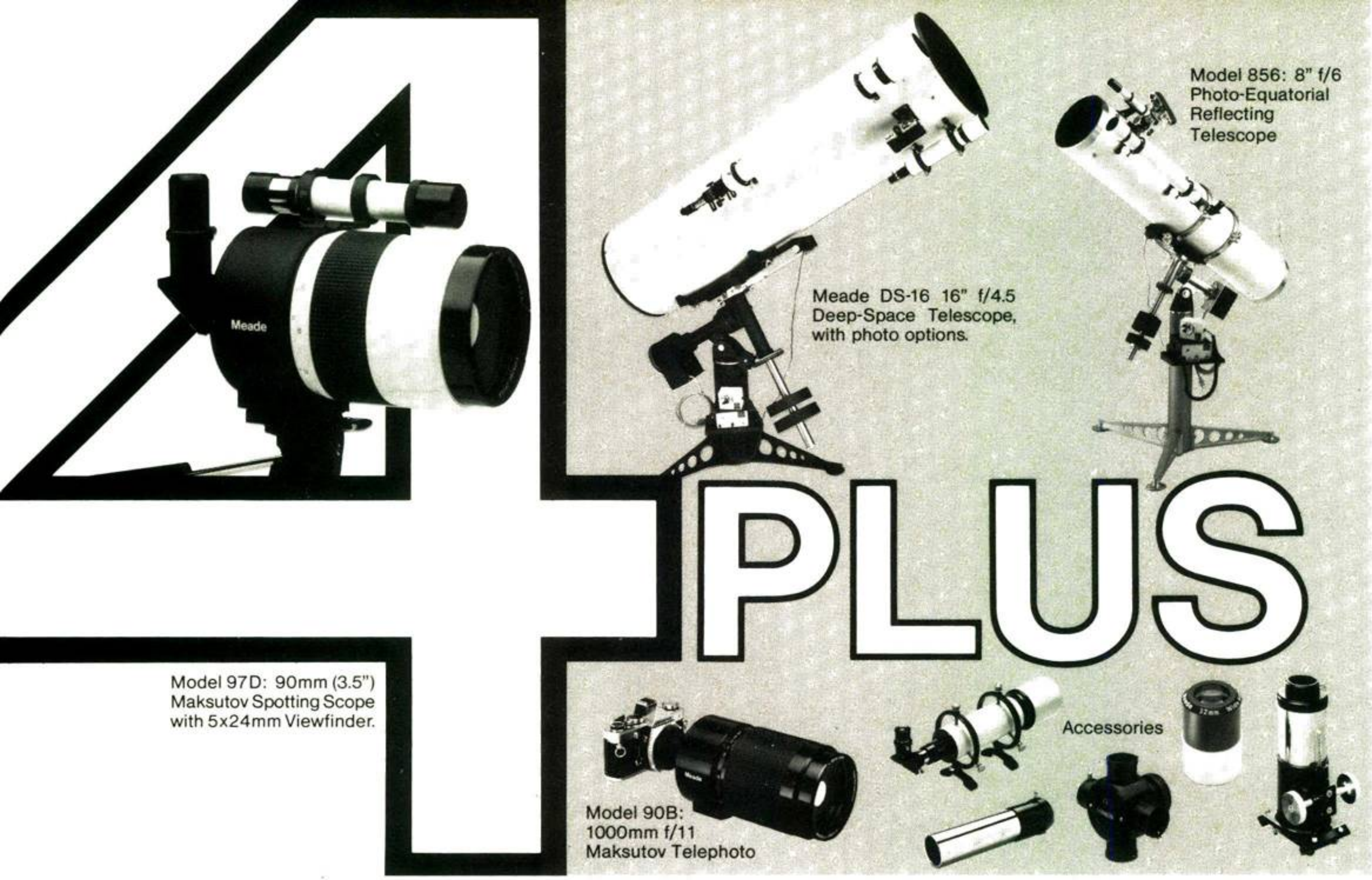

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Cover: Hydrogen, helium, carbon, oxygen, and traces of heavier elements — all baryonic matter — make up the nebula, stars, and dust lanes we see in Messier 8. But the matter we can see — here and everywhere else in the sky — accounts for less than 10 percent of the mass of the universe! This month ASTRONOMY explores the perplexing observations which have led astronomers to this astounding assertion. These pages: The Keyhole Nebula envelopes the bright star Eta Carinae. Photographs by Jim Barclay.

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Mystery of the Missing Mass

by Barry Parker

Fossils of Something Interesting: The Large-Scale Structure of the Universe

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by Ann K. Finkbeiner

Stars, gas, and dust swirl in an orgy of cosmic creation — but underlying this visible matter is a sea of exotic subatomic particles that account for the bulk of the mass of the universe. NGC-2264 and the bright star S Monocerotis. Photograph © 1981 by the Anglo-Australian Telescope Board.

Mystery of the Missing Mass

by Barry Parker

Most of the mass in the universe exists in some invisible form.

For years astronomers have faced a cosmic mystery so vast it defies the imagination: over 90 percent of the universe appears to be missing. Clusters of galaxies, superclusters, even individual galaxies — all appear to be missing much of their mass. Of course, the mass is not really missing. The mystery involves the form of the mass — mass that is not present as stars. It might be hidden as small dark stars, black holes, exotic subatomic particles, or in some mysterious form we do not yet know about.

The problem occurs when astronomers "weigh" galaxies, clusters, and superclusters of galaxies by their mutual gravitational attraction. The masses determined this way exceed the mass of the galaxy measured by its total light output. Clearly there's mass present which is not in the form of stars — if it were stars, we'd see their light. So the problem isn't really a missing mass problem, it's a "missing light" or "invisible mass" problem. In the case of the universe, however, we can call it a "missing mass" problem without embarrassment, since we're not sure the mass is actually there. What we do know, though, is that there is not enough mass, by several orders of magnitude, to hold the universe together.

The first inkling of this mystery came in 1933 when California Institute of Technology astronomer Fritz Zwicky studied the Coma Berenices cluster of galaxies. He determined the masses and motions of these individual galaxies, and found the masses too slight and motions too fast for gravity to bind the cluster together. The cluster should have been flying apart — each of the galaxies going its own way — but it wasn't. The only explanation Zwicky could come up with was that the cluster contained "dark matter," material that he could not see or photograph.

Astronomers soon began finding other clusters of galaxies with the same characteristics. And not just a small percentage *of their mass was missing; in some cases,* 50 to 100 times their measured mass was needed to hold them together.

Where is the mass? What form does it take? It was years before serious suggestions were forthcoming. Finally, in 1974, Jeremiah Ostriker, P.J.E. Peebles, and Amos Yahil proposed a way to solve this dilemma. They showed — theoretically — that if galaxies were to remain stable, they had to have considerably more mass than was observed. On this basis, the three astronomers suggested that galaxies are surrounded by halos extending far beyond the limit of visible stars. They were uncertain as to the makeup of the halo, but believed it was made up of faint low-mass, or even dead, stars.

***Mutual attraction by gravitation is one basis for determining* the masses of galaxies. The "missing mass problem" arose when the mass derived by this method greatly exceeded the *mass derived from adding up the "bright matter," the stars* and nebulae, within galaxies. Interacting galaxies NGC-5432 and NGC-5435 were photographed by the 120-inch Shane telescope at Lick Observatory. Lick Observatory photograph.**

Vera Rubin at Carnegie Institute came to much the same conclusion as a result of her study of galactic rotations. Let's take a moment to look at the technique she used. We know, for example, that the farther a planet is from the Sun, the longer it takes to orbit and the slower it moves in its orbit. Johannes Kepler discovered this precise mathematical relationship in the 17th century. The planets in the solar system move in accordance with Kepler's Laws: Venus travels at a slower speed than Mercury, Saturn at a slower speed than Jupiter, and Pluto travels slowest of all. This is called *Keplerian motion*.

For many years, astronomers assumed that the motion of stars within galaxies was also Keplerian. Galaxies are, after all, similar to our solar system in that they are systems of objects (stars, planets, gas) revolving around a common center. There is, of course, an obvious difference. In the solar system, virtually all mass is concentrated at the center, in the Sun. In a galaxy, though, the mass is spread throughout the stars, gas, and dust that compose it. If we assume that where there *is light there is mass*, we conclude that most of the mass is still near the center. Galaxies are brightest near the center and gradually taper toward the edges. On this basis, astronomers expected the motion to remain approximately Keplerian.

Unfortunately, this assumption is difficult to test. Individual stars can be seen in only a few nearby galaxies. Fortunately, the arms of spirals contain bright gas clouds — like the Orion Nebula. So with today's large telescopes and sensitive spectrographs, astronomers have been able to *measure velocities of rotation in many* galaxies.

This technique is quite simple: select galaxies that lie approximately edge-on, and record the spectra of outlying nebulae. The positions of the spectral lines are altered by their Doppler shift. If a nebula is approaching us, its spectral lines are shifted toward the blue end of the spectrum by an amount proportional to its velocity; if it is receding, the spectral lines are shifted toward the red. After appropriate corrections for the Sun's motion within our own Galaxy and our Galaxy's motion through space, we find that the lines of nebulae on one side of the galaxy are blue-shifted and red-shifted on the other. Plotting the distance from the center of the galaxy versus its velocity yields a *velocity of rotation* for the galaxy.

Using this technique, Rubin and her group determined that typical velocity curves did not drop off with increasing distance from the center — the expected result for Keplerian motion. Instead, they remained constant well beyond the visible edge of the galaxies studied. This meant that there had to be a considerable amount of matter in the outer regions of galaxies that couldn't be seen or photographed. By the mid-1970s, astronomers were reasonably certain that all galaxies had gigantic halos of dark matter (see "A Bigger and Better Milky Way Galaxy," January 1984, ASTRONOMY). The rotation curve evidence shows that the visible parts of galaxies accounted for only about two percent of their overall mass.

Upon examination, superclusters of galaxies were also found to be too faint to explain their masses by starlight. In fact, the problem is generally more extreme for superclusters, which often need several hundred times the mass detected. The problem did not end here. Cosmologists had known for years that there did not appear to be enough matter in the universe to ultimately stop its expansion. Visible matter accounts for only about one percent of the density needed to stop expansion. Even when mass that probably exists but can't be seen is added, we still have only a small percent of what is needed to close the universe.

Astronomers were in a quandary wondering where the missing mass was. It could not be seen, photographed, recorded by radio astronomers, or detected by its X-ray emission. It couldn't be thin gas spread between the galaxies since this had already been detected and added to the "visible" mass. Obviously, whatever it was, it didn't emit enough radiation to detect. The missing material didn't appear to obscure background material. And since the mass of intergalactic absorbing material had also been added in, it couldn't be dust.

To complicate matters further, remember there are two "missing mass" problems: one involves the invisible mass of galaxies and groups of galaxies, and the other concerns the missing mass of the overall universe. Are both "missing matters" the same? We cannot yet answer this, but it seems reasonable to assume that they are.

Over a period of several years, astronomers considered many candidates, but one by one they were eliminated. Was the missing mass hydrogen gas? All three forms — atomic, molecular, and ionized — were considered and rejected. The first two would give rise to a 21-centimeter radiation which could easily be detected. For a while, ionized hydrogen seemed a good candidate — it could give rise to X-rays and a faint X-ray background was detected. It was later shown, however, that the X-rays were caused by quasars. Other things such as low-mass stars (brown dwarfs), proto-stellar lumps that failed to become stars ("Jupiters"), and dust and rocks were considered, but again they were shown to be poor candidates (see "Brown Dwarfs and Black Holes," April 1978, ASTRONOMY). All would make our universe much dustier than it is, even taking into account the dust-revealing observations of IRAS (see "IRAS: Mission Infrared," March 1984, ASTRONOMY).

Radiation was also considered. It is, after all, just another form of matter. When the calculations were made, however, they showed that radiation contributes very little to the overall mass. White dwarfs, neutron stars, and black holes were considered poor candidates because, if they made up the missing mass, these objects would produce effects that had not been observed. Although all of these exist, they do not account for 10 times the observed luminous mass of our Galaxy.

By the late 70s, astronomers were beginning to understand the events that took place shortly after the Big Bang and the problem took on a new twist. About three minutes after the universe began, the first atomic nuclei formed. This time is called the *era of nucleosynthesis*. One of the events that took place during this era was the build-up of helium nuclei from deuterium nuclei. A deuterium nucleus hit by a neutron becomes a tritium nucleus, and within a short time the tritium reacts with a proton to become helium.

If the early universe had been dense, a large number of collisions would have taken place and most of the deuterium would have been converted to helium. If the density was low, on the other hand, few collisions would have occurred and considerable amounts of deuterium would have survived. By measuring the amount of deuterium remaining in the universe now, we can determine what its density was back then and work forward to determine the average density of the universe today. A similar estimate comes from helium. These measurements indicate that the density should be well below critical density which implies an open, ever-expanding universe.

Yet, as with so many other things, there is a loophole in the argument. It applies only to heavy particles, such as protons and neutrons, called *baryons*. The deuterium-helium evidence implies that the missing mass could not be baryons, and thus the universe cannot be closed with baryons. Therefore we must exclude such things as dwarf stars, hydrogen gas, dust, and even black holes as the bulk of the "missing mass." Considerable mass is in the form of baryonic material, but the mass deficiency is so large that most of it must be in the form of exotic subatomic particles.

Baryons are not the only particles in the universe. There are also *leptons*, a class of particles that includes the electron, the muon, and their antiparticles. When we observe particles other than baryons, we can realize how lucky we really are: these particles are elusive bits of matter whose existence is, in many cases, still speculative. Nevertheless, astronomers concerned with the missing mass problem have embraced them eagerly.

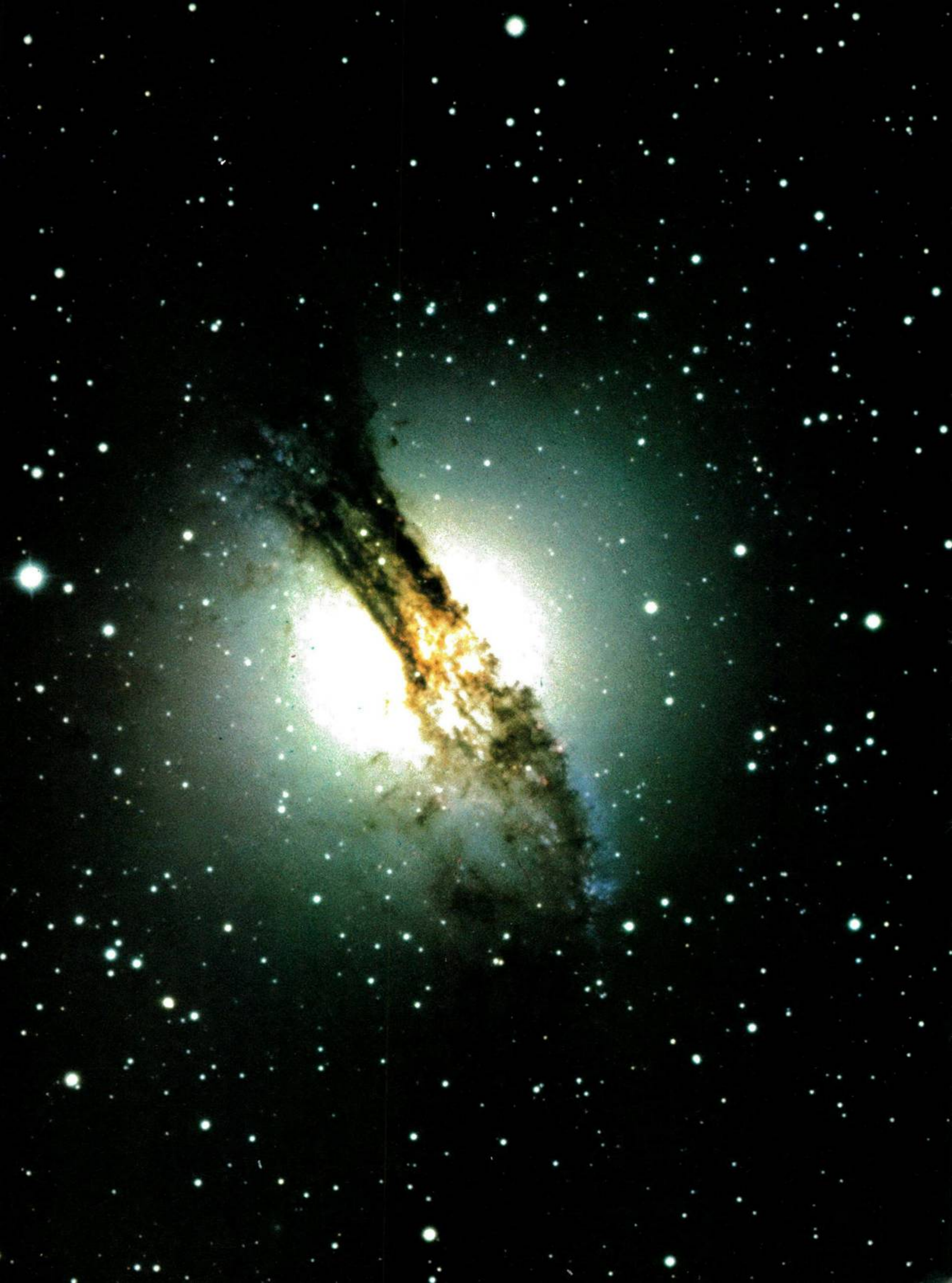
The first of these exotic particles to excite astronomers was the lepton known as the *neutrino*. Although we've known about neutrinos for many years, they had not been previously considered because physicists assumed that they have zero rest mass. (They do have an energy equivalent mass, but it is much too small to make a significant contribution.)

As the theory of the early universe developed, it became clear that there should be many neutrinos in existence — as many neutrinos as there are photons, or about 10 billion neutrinos for every atom! If neutrinos had even a tiny mass — say one hundred-millionth that of a typical atom — they would obviously make a significant contribution to the total mass of the universe, or even outweigh everything else!

The suggestion that the neutrino might have a small

Silhouetted against a background of stars, the small dark nebula Barnard 86 contains non-luminous matter. But dark nebulae cannot account for all the missing mass, nor even a tiny fraction of it. The blue stars of open cluster NGC-6520 shine in the same field. Photograph © 1980 by the Anglo-Australian Telescope Board.

Long before astrophysicists knew anything of brown dwarfs, black holes, neutrinos, magnetic monopoles, or axions, they knew the total mass of clusters of galaxies was too large to be explained by stars and gas alone. This rich cluster of galaxies in Hercules was photographed with the 200-inch telescope on Palomar Mountain. Palomar Observatory photograph.



mass was supported by an important class of theories proposed in particle physics a few years ago. These theories represented an attempt to unify several basic forces of nature and are referred to as Grand Unified Theories, GUTs. Although some versions suggest that neutrinos have a small mass, GUTs do not imply that they *must* have mass. And detecting the mass is difficult — physicists have shown that the most likely mass for the neutrino is at, or beyond, the present limits of direct detectability. Nevertheless, physicists continue looking for ways to weigh this particle.

We now know there are actually three types of neutrino: an electron neutrino, a muon neutrino, and a tau neutrino. The tau netrino has never been detected, but high-energy physicists believe it exists. If the three types of neutrino have mass, and at least two of them are different, then in the strange realm of sub-atomic physics, neutrinos should oscillate back and forth between types. An electron neutrino might change into a muon neutrino for a while, then switch back to being an electron neutrino. Experimental verification of "neutrino oscillation" would prove that the neutrino has mass. F. Reines, H. Sobel, and Elaine Pasierb of the University of California decided to check this possibility, and in 1980 they announced they had detected the oscillation. Apparent verification from a Russian team, using a different technique, came shortly thereafter.

Considerable excitement was generated by these announcements. More experiments were performed to check the results, but verification has not followed. In 1981 one group at the Centre Europeen pour la Recherche Nucleaire (CERN) in Switzerland looked for oscillations and found none (or at least placed an upper limit on them); another group at CERN arrived at the same conclusion. In America, a group at Fermilab also checked for oscillations and found none. The experiment is, of course, very difficult. The lack of verification does not necessarily rule out a mass, although it does cast doubt on the possibility. Many astronomers, however, are still hopeful.

The lack of verification has not deterred cosmologists, either. There were several serious problems with their theories and they hoped that massive neutrinos might prove to be the "missing ingredient" in making them work. One problem, in particular, related to the development of galaxies. Astronomers are quite certain that galaxies developed from "lumps" in the primordial soup that exploded out from the Big Bang; but how these lumps form and develop remains uncertain because they tend to dissipate, rather than form galaxies. Once the suggestion of neutrino mass had been made, astronomers were eager to model the effects massive neutrinos might have had on the formation of the universe (see "Cosmology on a Computer," June and July 1983, ASTRONOMY).

Another problem also came to light; on the scale of superclusters of galaxies, astronomers found that the universe is not uniform, as had previously been assumed. Instead, the universe showed an unexpected but distinct structure. Clusters of galaxies appeared strung out in gigantic strings, and between these strings were huge voids where there were no galaxies (see "Superclusters," April 1984, ASTRONOMY). It almost appeared as if the universe were composed of enormous empty cells, with galaxies lying only at the edges of these cells.

Calculating the evolution of primordial matter into galaxies is extremely complicated, but giant computers and long computer runs have accomplished this seemingly impossible task. With neutrinos thrown into the primordial cosmic soup, matter would ripple and become lumpy, condensing into gigantic strings of galaxies with voids between them.

But there is a problem: the two principal theories describing the large-scale structure are in serious conflict. Yakov Zel'dovich and his group at Moscow University are convinced that galactic-cluster-sized clouds of matter form first, then fragment to form individual galaxies. A number of astronomers in the west, on the other hand, are sure there is considerable evidence to disprove the Soviet theory. P.J.E. Peebles of Princeton, for example, points out that a large number of clusters of galaxies are not found in superclusters; rather they are on the outskirts of the superclusters and presumably moving toward them. Based on this and other evidence, Peebles believes that galaxies form first, then later gather into clusters and superclusters.

Zel'dovich and his colleagues have developed the "pancake theory," which incorporates massive neutrinos with some success. After the primordial soup fragments and large clumps began to collapse, the Soviet group argues, they did not collapse equally in all directions. Instead, they collapsed into gigantic, flattened "pancakes" of matter. Most of the galaxies then formed in the dense regions at the intersections of these pancakes.

Zel'dovich's theory recently got a shot in the arm when Stanislav Djorgovski of the University of California used photometric observations of galaxies in the Coma cluster to show that the long axes of individual galaxies are generally aligned parallel to the major axis of the cluster. This would happen only if stringlike shapes formed first, then fragmented into individual galaxies. It could not occur if the individual galaxies formed first and then collected into clusters.

Although the theory has been successful in predicting supercluster formation, Paul Shapiro of the University of Texas, Curtis Struck-Marcell of McDonald Observatory, and Adrian Melott of the University of Pittsburgh have shown that the model is barely able to generate individual galaxies. This hasn't necessarily invalidated the theory, but does make astronomers wary of it.

There is still hope today for massive neutrinos as the missing mass, but because of serious difficulties with both the cosmological theories that incorporate neutrinos and with measurement of neutrino masses, many astronomers have looked beyond neutrinos.

Some have taken a second look at black holes. Black holes which result from the collapse of giant stars and supernova explosions are out of the running because they consist of baryonic matter. But these are not the only type of black hole in the universe. Stephen Hawking of Cambridge University showed many years ago that another type of black hole exists, which we now call *primordial black holes*. If the Big Bang explosion was inhomogeneous, which we are certain was the case because galaxies wouldn't have otherwise formed, then black holes should have been generated as matter was

NGC-5128 sports a ring of dark dust, gas, young stars, an extended halo of dim red stars, great lobes of hot tenuous gas observed at radio wavelengths, and a supermassive black hole in its core, yet all these extras do not add sufficient material to explain the total mass of the system. What, then, is the form of the missing mass? Photograph © 1980 by the Anglo-Australian Telescope Board.

Candidate	Positive Features	Problems
Massive Neutrinos	1. Predicted by GUTs. 2. Can form superclusters. 3. Would be generated in early universe.	1. Mass may have been detected, but not verified. 2. Cannot form galaxies easily. 3. May be too energetic to settle down.
Planetary Mass Black Holes	1. Would be generated in early universe. 2. Can act as seeds for galaxies.	1. Exist only on paper.
Magnetic Monopoles	1. Large mass. 2. Predicted by GUTs.	1. May have been detected, but not verified.
Massive Gravitinos (photinos and other -inos)	1. Predicted by supergravity. 2. Can form galaxies.	1. Cannot form superclusters. 2. Exist only on paper.
Axions	1. Nonenergetic, light particles that should settle down easily around galaxies, even dwarf galaxies.	1. Exist only on paper.

compressed. A whole range of black holes could have been generated — from those smaller than an atom to monsters holding the mass of a galaxy. Just as the baryon loophole allowed us to consider neutrinos, there is also a loophole here. Many of these black holes formed before the era of nucleosynthesis, so the density of the universe determined from the deuterium-helium argument doesn't include them.

When we examine the situation further, we find that a problem still exists. In addition to predicting that primordial black holes exist, Hawking also showed that they eventually explode. According to his calculations, black holes have a finite surface temperature. In the case of those with stellar masses, this temperature is only an infinitesimal fraction of a degree above zero; but in the case of small black holes, it can be quite large. In short, the smaller the black hole, the higher its surface temperature. This means that as a black hole radiates away its energy, it grows hotter and smaller and smaller and hotter until finally — in its last stages — it literally explodes.

Hawking has shown that all black holes which were formed with an original mass less than 10^{15} grams have now exploded, and must therefore be eliminated from consideration. Massive black holes, on the other hand, must also be eliminated. If they existed in sufficiently large numbers to account for the missing mass, some would likely be present in clusters of galaxies. They would also gravitationally perturb the galaxies around them as well as the microwave background, yet no evidence of such perturbations has been found in either instance.

Finally, and perhaps most important, large black holes form later than smaller ones; those more massive than our Sun would have formed *after* the era of nucleosynthesis. For this reason, it is generally accepted that black holes with masses between 10^{15} and 10^{32} grams are the best candidates. Because this is in the range of planetary masses, these black holes are sometimes called planetary-mass black holes, or *PMBHs*. Once again, as with massive neutrinos, it is difficult to detect PMBHs directly.

Cosmologists have wondered if black holes might act as seeds around which galaxies form. Katherine Freese and David Schramm of the University of Chicago, and Richard Price of the University of Utah have recently shown this is possible. They point out the likelihood of small fluctuations in background density of these black holes when they formed. Such nonuniformity would eventually lead to clusters of black holes. Once clusters formed, they would attract baryonic matter. Then the black holes would explode, releasing energy, which would sweep up considerable matter and eventually become the seed of a galaxy. These researchers also pointed out that the galaxies could attract and trap PMBHs; therefore, these dark halos of galaxies might consist of planetary-mass black holes.

Another, perhaps better, candidate which has received widespread attention recently is the *magnetic monopole*. The major problem with magnetic monopoles is that we do not know whether they exist. Magnets have both a north and a south pole; they are dipolar. If you cut a magnet in half, the two halves are similar to the original magnet in that both have north and south poles.

If you cut them in half again, the same result occurs — you get two-pole magnets. It seems impossible to separate the poles. In this respect, magnetism differs from electrical charges where positive and negative charges exist separately. But many scientists are convinced that isolated magnetic poles — monopoles — do exist. According to our understanding of the early universe, magnetic monopoles were created in large numbers and some of them should have survived to the present.

Interest in monopoles began in 1931 when physicist Paul Dirac of Cambridge University predicted their existence. Unfortunately, there was a slight problem with the monopoles he predicted — they had "tails" and nobody was quite sure whether this had any physical significance. Nevertheless, several searches were initiated, but the task proved more difficult than originally anticipated. No one knew how the monopoles would act, how fast they would travel, or what their mass was. Dirac's theory didn't predict this.

Despite these uncertainties, the researchers continued for many years, searching the Earth's atmosphere, interior, and pole caps. They even looked among Moon rocks. Nothing was found. A breakthrough finally came in 1974: Gerard t'Hooft of the State University of Utrecht in the Netherlands, and A. Polyakov of the USSR proved independently that monopoles were predicted by GUTs. This time their mass was calculable, and this time they didn't have tails. Much to their surprise, though, the predicted mass was huge — 10 million billion proton masses. This explained why earlier searches had been unsuccessful. Yet if this was the case, something was drastically wrong. According to the theory of the early universe, monopoles were as common as protons and neutrons; with their tremendous mass, they would have literally overwhelmed the universe. The missing mass problem suddenly became the excessive mass problem: a universe full of such monopoles would have collapased back on itself just 10,000 years after the Big Bang!

Blas Cabrera of Stanford University considered this difficulty and concluded that the number of monopoles must have been diluted. He did not concern himself with *how* the dilution had occurred, but rather with how many monopoles would be needed to just barely close the universe. His calculations suggested that with the appropriate apparatus, he should be able to detect about two a year. He built the necessary equipment and waited; six months passed and nothing happened. Finally, on February 14, 1982 Cabrera received a Valentine's Day gift: the needle moved, indicating a monopole had passed through. Being naturally cautious, he hesitated to announce his discovery until the event had been thoroughly checked. But to Cabrera's embarrassment, news leaked out and was picked up by the public press. Eventually, after a careful and thorough check, he could find no other explanation and published a short report.

Another announcement came in 1984: a group working under S.N. Anderson at the University of Washington reported detection of five monopoles. Because a completely different technique was used, these did not necessarily verify Cabrera's discovery. Many scientists remain skeptical. The reason is E.N. Parker's research at the University of Chicago in 1970, which revealed monopoles could destroy the magnetic field of our Galaxy. According to Parker's calculations, if the density of monopoles were high enough to detect two monopole events per year, the field would have been destroyed. However, our Galaxy has an observable field. Parker believes there are a hundred thousand times fewer monopoles than Cabrera predicts.

Other scientists do not agree. Ira Wasserman of Cornell University argues that magnetic monopoles captured by galaxies would *enhance* the field rather than destroy it. There's also the problem of the GUTs prediction, according to which we should be flooded with monopoles — and this doesn't seem to be the case. What happened to these monopoles? One possible explanation arises from a variation of the Big Bang theory recently put forward by Alan Guth of MIT termed the *inflationary universe* (see "The Planck Era," March 1984, ASTRONOMY). Guth postulates a sudden and dramatic "inflation" of the universe about 10^{-35} seconds after it began — an event that explains much of the weaknesses of the standard theories. One thing the cosmic inflation phase does is decrease the number of monopoles; in fact, it decreases them so much that there may be only one or two left in the observable universe! Inflation theory is far from accepted; while it explains many things that were previously unexplained, it brings along its own problems.

Despite the difficulties and uncertainties, scientists are continuing several new experiments in their search for monopoles. Some of these are much more sensitive than the experiments performed by Cabrera and Anderson, so with a little luck we should know within a few years whether or not monopoles exist. If they do, it is quite possible that monopoles comprise the missing mass.

While many scientists were looking for the missing mass in the form of monopoles, some have been looking at other exotic particles. Exotic particles with the desired characteristics are predicted by a theory called supergravity. To understand supergravity, it is best to first take a brief look at the related theory of general relativity. After formulating general relativity in 1915, Einstein became interested in extending it to all phenomena — particularly to the microcosm. His was a theory of gravity, but he knew of another force besides gravity — electromagnetism. Two other fundamental forces have since been discovered, but these were unknown when Einstein started work on his theory. (Later, when they did become known, Einstein still ignored them.) He wanted a theory that unified the gravitational and electromagnetic fields, and at the same time bridged the gap between general relativity and quantum theory. Einstein spent the second half of his life attempting to unite these, but never did.

Scientists are still searching. The various GUTs attempt to unite electromagnetism with the two nuclear forces — the weak and strong interactions. But GUTs say nothing about gravity. Supergravity is an attempt in the same direction as GUT, but one that includes gravity. According to this theory, a single force fragmented as the universe expanded and cooled. We see these fragments as gravity, electromagnetism, and the two nuclear forces. Supergravity predicts the occurrence of many new and strange particles, sometimes referred to as superparticles. Each of the known particles has a superpartner; for example, corresponding to the electron there is the selectron, and to the photon, the photino.

The foundations for this theory were discovered by several Soviet physicists in the early 1970s. Western scientists took little notice of the discovery; but later in 1975, Bruno Zumino of CERN and Julius Wess of the University of Karlsruhe in Germany published a paper reinventing and extending the Russian results into what they termed "supersymmetry." The theory was still lacking at this point, though — it said nothing about gravity. In 1976, however, gravity was added and the theory began to attract considerable attention. Examining the details of this theory, scientists found it predicted a particle of the gravitational field — the *graviton*. Gravitons play the same role in relation to gravity as does the photon in electromagnetic theory: they propagate the field, but are massless. Along with the graviton comes its superpartner — the *gravitino*. The gravitino has recently received much attention because it can possess a mass.

Gravitinos should have been created in large numbers in the early universe — a fact that soon came to the attention of cosmologists. How would the universe evolve if it initially contained a background of gravitinos? Gravitinos are much less energetic than neutrinos and therefore are more capable of having formed galaxies in the early universe. They could easily have settled down into galaxy-sized objects — in fact, calculations show that objects about the size of galaxies form naturally in a gravitino-dominated universe. Cosmologists were elated, but when they pushed their calculations to larger masses — superclusters — their luck ran out. It is difficult, if not impossible, to form long chains and voids using gravitinos. While neutrinos could form superclusters but not individual galaxies, gravitinos could form galaxies but not superclusters.

However, the ability to form galaxies and clusters of galaxies is not enough. A further constraint is missing mass in low-mass dwarf galaxies. Marc Aaronson of Steward Observatory has shown that these diminutive galaxies — like their larger brothers — have massive halos, but neither neutrinos nor gravitinos are good candidates to explain their missing mass. Both are too energetic to remain in a dwarf galaxy's halo.

In addition, there are other supergravity particles — photinos, winos, and so on — but a nagging question remains: Do these particles really exist? So far we haven't detected any of them, though high-energy physicists feel confident we will and their predictions have often proven true in the past. Is there anything else that would work? Ideally, it should be an exceedingly light particle — something a trillion times as light as an electron which can easily settle down around dwarfs. Such a particle may exist — the *axion* — but from an observational standpoint, it is no better than the particles we have just discussed. The axion exists only on paper.

We have seen that there is a considerable amount of mass in the universe which has not been accounted for. We know it can't be baryonic matter. This seems to leave only exotic particles and black holes. It will be a disquieting universe, indeed, if we find that its visible parts — stars, galaxies, planets, humans — are but a minor baryonic contaminant adrift in a sea of exotic particles. Which of these particles is it to be: neutrinos, monopoles, planetary-mass black holes, gravitinos, axions, or something we aren't aware of? We don't know yet — but hopefully, we will discover the answer in the next few years.

Fossils of Something Interesting: The Large-Scale Structure of the Universe

> *"Clustering is a fossil of some sort, a remnant of processes in the distant past."*
> — James Peebles, 1980

On a large scale, the universe we see is lumpy. Stars crowd into galaxies. Galaxies knot together in great clusters. Superclusters of clusters run in bright streams over hundreds of millions of light-years.

On an even larger scale, the universe is filled with smooth, cold, invisible microwave radiation, a kind of "light" that is the trace of an earlier era — a time when the universe was a viscous fluid as smooth and uniform as this light appears today.

Cosmologists do not know how all that lumpiness — which they term "structure" — came out of all that smoothness. Every tentative solution meets some contradiction, some observation (or lack of one), or the reply "not likely."

For hundreds of years, astronomers have fixed the positions of stars and galaxies in two coordinates on the sphere of the sky. They don't use longitude and latitude as on a terrestrial globe, but rather plot right ascension and declination, respectively, on the celestial sphere. By the 1930s, astronomers had compiled catalogs of the positions of galaxies. Harlow Shapley and Edwin Hubble of Harvard College Observatory noted that fully twice as many galaxies inhabit the northern half of the celestial sphere as the southern half. It was the first hint of structure on a truly vast scale. Twenty years later, Gerard de Vaucouleurs of the University of Texas at Austin realized that the northern hemisphere looked well-populated because it is home of the Virgo Supercluster, a loose conglomerate of around 50 clusters of galaxies. One of them — the Local Group — is ours.

In 1958, George Abell of the University of California at Los Angeles, compiled the first catalog listing positions of the brightest and richest clusters of galaxies. A few years later, Fritz Zwicky of the California Institute of Technology published a similar catalog of the less populous and poorer clusters. Clustering now seemed obvious, but was still unproven.

Then in the 1970s, James Peebles used the Lick catalog of galaxies compiled by Donald Shane and Carl Wirtanen to publish a map of the sky, a dramatic and beautiful image of one million galaxies. The map looks as though someone threw iron filings on a plate, then briefly passed a magnet under it: while there is no obvious order, it is not exactly random either.

By 1977, Peebles had analyzed this apparent clustering mathematically. He used a statistical procedure called a correlation, or covariance, function. Roughly speaking, a correlation function will tell you what the chances are of finding a neighbor living one, two, or three blocks away — in a landscape the size of the universe. Peebles found that galaxies are more likely to be found in the neighborhood of other galaxies and, like people, they tend to cluster.

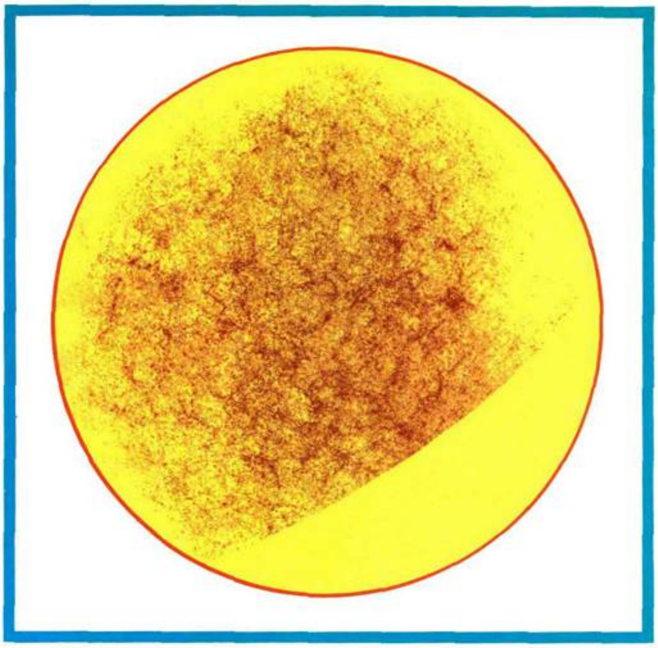
Despite the mounting observational evidence of clustering, astronomers insisted that the universe must also be uniform. Both Einstein's theory of general relativity and Hubble's observation of the uniform recession of galaxies asserted this central tenet of astronomy: no matter where you stand and no matter where you look, the universe will appear the same. In 1935, Edward Milne named this the Cosmological Principle and it still holds true today.

In 1965, Bell Laboratory physicists Arno Penzias and Robert Wilson confirmed the Cosmological Principle by detecting microwave radiation coming evenly from all directions at a temperature of three degrees above absolute zero. James Peebles, Robert Dicke, and their colleagues at Princeton University identified this radiation as a remnant of the birth of the universe — the "glowing ember" of the Big Bang.

This three-degree background originated when the universe, although much hotter, was exactly smooth; a glowing ocean like the interior of a star, hot, brilliant, opaque. More precisely, it was a mixture of leptons (electrons, neutrinos, and the like), baryons (protons, neutrons, and the like), and photons (the little particles of light, of radiation). The electrons and photons collided constantly, with the result that the energy of the photons was high, as was the pressure they exerted, the radiation pressure. Occasionally, electrons and protons would collect in some places, or thin out in others. Whenever one of these denser fluctuations showed any sign of becoming permanent, radiation would disperse it. Radiation's outward push overcame the inward pull of gravity. As long as this happened, the density of the universe remained, on the whole, uniform.

But the universe continued expanding and cooling. When the temperature dropped to 4,000 degrees above absolute zero, matter and radiation "decoupled." Photons were losing so much energy that radiation pressure could no longer disperse whatever fluctuations were taking place. Electrons became free to join protons in hydrogen atoms, and atoms were free to attract each other gravitationally. At decoupling time, some 100,000 years after the Big Bang, the universe darkened and became transparent; nothing impeded hydrogen atoms from growing into galaxies, clusters, and superclusters. As the universe expanded, the radiation continued to cool from a 4,000 degree light to an infrared glow and then finally to the cold microwave background radiation we see today.

The three degree background is a clue. Any variation in its present uniformity is a sign of fluctuations at the time of decoupling. Since its discovery, the three degree background has been precisely measured. So far, the most exacting observations have revealed no variation in its uniformity greater than one part in 10,000. Even in the intervening 15 billion years, gravity cannot collapse a fluctuation that slight into a galaxy.



From a deep survey of galaxies, subtle patterns emerge. Galaxies clearly cluster, and perhaps lie in long chains or filaments across the sky. Shown is the entire northern hemisphere of the sky centered on the north galactic pole. Map by M. Seldner, B.L. Siebers, E.J. Groth, and P.J.E. Peebles.

Another approach is to assume that the fluctuations were random. The universe should have no preference for any particular size of lump. Random processes obey what mathematicians call Poisson statistics. To model random fluctuations, a statistician fills the universe with identical boxes, each the size of a typical galaxy. If he wants to know the average fluctuation in the number of hydrogen atoms in the boxes, the statistician counts the particles in a typical box. A galaxy-sized box should contain 10^{70} hydrogen atoms. Poisson statistics tells him that the count from one box to the next will vary by an average of 10^{70} divided by the square root of 10^{70}. In other words, the fluctuations will differ from each other by an average of one part in 10^{35}, an extraordinarily small number. Notes Arthur Rivolo of the Space Telescope Science Institute, "There's no way gravity can take a fluctuation that size and, during the age of the universe, make a galaxy out of it." Whatever the fluctuations were, they were not random.

If initial fluctuations will not tell how structure grew out of uniformity, then perhaps the nature of the structure we see now will.

The universe is roughly 15 billion years old. It was a smooth fluid until some 100,000 years after the Big Bang. Quasars, which may be young galaxies, formed some four billion years later. Galaxies are metal-rich with the remnants of supernova explosions. They formed early and were mature when nine billion years old. Our Local Cluster is apparently just now forming: galaxies in our neighborhood are moving apart more slowly than galaxies that ride the general expansion of the universe. The same is true for other clusters in our neighborhood: they appear to be coming together, falling into our Local Supercluster. Possibly the supercluster is just forming too.

Extended massive halos envelop all galaxies. Some of the material around the giant elliptical galaxy NGC-1399 is visible as globular clusters, but even more material *cannot* be seen. Photograph © 1977 by the Anglo-Australian Telescope Board.

In the early 1970s, James Peebles made an obvious suggestion. The original seeds must have been galaxy-sized, somewhere around 10^{12} times the Sun's mass. The galaxies attracted more mass and other galaxies, then formed clusters, and eventually superclusters. His so-called *hierarchical* model predicted that galaxies, in spite of their tendency to cluster, should be randomly distributed. Voids in the distribution would be moderate, and clumps, or filaments, small.

The problem with this model is that it had to assume completely *ad hoc* non-random fluctuations in the early universe. Furthermore, subsequent calculations showed that if galaxy-sized fluctuations were supposed to grow into superclusters — which we *know* exist — they'd need longer than the present age of the universe to form. Gravity didn't act quickly enough.

Around the same time, Yakov Zel'dovich of the Institute of Applied Mathematics in Moscow proposed a different scenario. He called it the "pancake theory"; others call it the adiabatic theory. (Peebles calls it the top-down theory — as opposed to his own, the "bottom-up.") Zel'dovich suggested that radiation pressure would have wiped out all but the very largest fluctuations. At the time of decoupling, any surviving seeds would have been as huge as superclusters with masses 10^{15} times that of the Sun. He proposed that these seeds collapsed into wide, flat, pancake shapes. Along the edges of the pancakes and where several pancakes intersected, strings of higher-density pancakes formed. These pancakes later flaked apart to form clusters and later galaxies. The centers of these pancakes eventually thinned out into voids, and their edges formed filaments of supercluster length.

The pancake theory predicted observers would find filamentary superclusters strung around huge voids while isolated galaxies would be rare. The theory also predicted that clusters and galaxies formed late. Once again the problem here is time: galaxies are ancient formations half the age of the universe.

Both the top-down and bottom-up theories were incorrect, or at least incomplete. Astronomers needed more information on the distribution of galaxies in the universe. Previous catalogs — the Lick catalog of galaxies, Abell's and Zwicky's catalogs of clusters — located galaxies in two dimensions only. The third dimension — distance — depended on the measurement of redshift. In 1929, Edwin Hubble noticed the relation between an object's distance and the degree to which its light is shifted toward the red end of the spectrum. The further the object, the greater its redshift. By the 1950s, measuring the redshift of a single galaxy from a photographic plate took about one hour. By the late 1970s, however, astronomers were using electronic detectors to decrease the required observation time to a few minutes per galaxy. For the first time, they could survey large areas of the sky in three dimensions.

Previous guesses now became the observed facts of galactic distribution: great chains of galaxy clusters span the sky. Some chains are sequences of knots, some have weak links, and some hold a few clusters. None seem gravitationally bound. Unmistakably, however, the eye sees streams of high galaxy density.

In 1976, William Tifft, Stephen Gregory, and Herbert Rood, and Guido Chincarini independently found that the cluster in the Coma Berenices stretches an arm out to a nearby cluster known as Abell 1367 and between these two galaxy-rich clusters are several galaxy-poor clusters with similar redshifts. The whole chain extends 70 million light-years from end to end. A few years later, the same researchers located a small supercluster in the constellation Hercules. In 1981, Tifft, Gregory, and Laird Thompson identified the Perseus-Pisces Supercluster. A year later, Riccardo Giovanelli and Martha Haynes used radio waves to find a supercluster in Lynx and Ursa Major. This area lines up with the Perseus-Pisces supercluster and is possibly part of it. The assemblage looks distinctly filamentary, extends 700 million light-years, and crosses the entire night sky. (See "Superclusters: Giants of the Cosmos," ASTRONOMY, April 1984.)

But theory had also predicted that areas of high density ought to coexist with areas of emptiness. Between 1980 and 1982, Robert Kirshner, Augustus Oemler, Paul Schechter, and Stephen Schechtman found a huge "hole" in the constellation Bootes. They found plenty of galaxies out to 750 million light-years and galaxies beyond 1100 million light-years, but in the intervening 300 million light-years they saw practically none. They called this the Bootes Void.

In 1981, Marc Davis and John Huchra of the Harvard-Smithsonian Center for Astrophysics began systematically collecting redshift data on 2400 galaxies in our Local Supercluster. They found what they thought were filaments of a large-scale structure.

So far, the discoverers of the superclusters had taken redshifts selectively, in their particular areas of the sky. Like the discoverers of galaxies and clusters in the 1950s and 1960s, they still needed confirmation. In 1983, Neta Bahcall of the Space Telescope Science Institute and Ramond Soneira of Princeton University duplicated the strategy Peebles has used to prove clustering and employed his correlation function. From a list of rich clusters compiled by George Abell, Bahcall and Soneira correlated positions in three dimensions and found something remarkable: the correlation for clusters is 20 times that for galaxies. In other words, a cluster is 20 times more likely to be in a supercluster than a galaxy is to be in a cluster. They also found superclusters extending 300 million light-years, "and I still can't tell you where they end," Bahcall said.

Interestingly enough, two of the biggest superclusters fall on either side of the Bootes Void. As Bahcall put it, the universe shows "a random sea of galaxies" affiliated rather loosely with some larger structure, although most of the clusters are in superclusters. Bahcall and Soneira created the first catalog of superclusters, 20 in all.

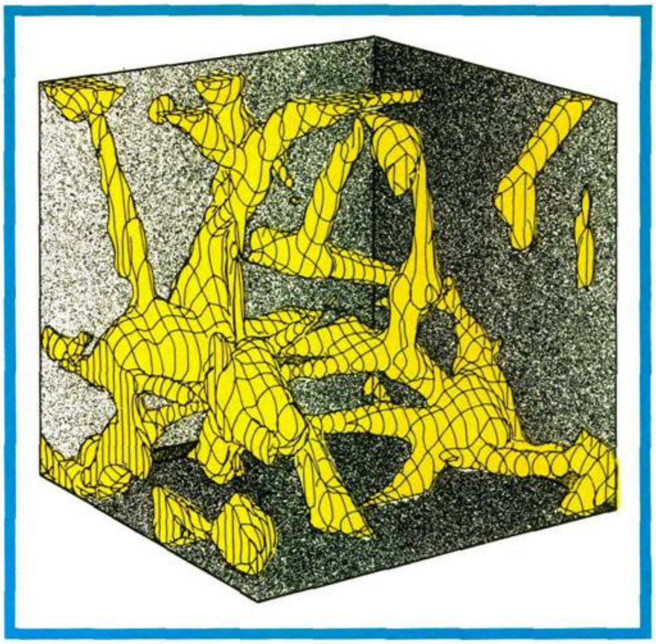
These observations helped fill the gaps of previous incomplete theories. Zel'dovich's pancake theory, despite giving the wrong age for galaxies, correctly predicted gigantic filaments and voids. Zel'dovich found he could fill the voids if, at photon decoupling, matter were somehow lumpy while the radiation was smooth. Could there be a particle heavier than the photon, yet existing in the same numbers, that would decouple sooner? If so, these particles would be free to attract each other, clump together and form little gravitational traps. Then at photon decoupling, the hydrogen atoms would be attracted to these denser regions. If this particle existed, and if it were as numerous as the massless photon, it could make up most of the mass in the universe. What could it be? And if it were there, why didn't we see it?

Curiously, astronomers were asking the same questions about what they called the "missing mass" problem (see "The Mysterious Missing Mass," this issue of ASTRONOMY). As early as 1933, Fritz Zwicky noticed that galaxies in the Coma cluster were moving so fast that the cluster should be flying apart. He speculated that some extra mass must hold the cluster together, but that the extra mass was invisible. By the 1970s, Zwicky's suspicions about missing mass were confirmed. Vera Rubin of the Carnegie Institute in Washington found deviations caused in the way spiral galaxies rotated that could only be caused by a massive, stabilizing, but non-luminous halo. What has come to be called "dark matter" doubles the size of galaxies and fills much of the space between neighboring galaxies. Dark matter seems to comprise 80 to 90 percent of the mass of the universe, and we don't know what this dark matter is.

Some believe this mass is a tiny lepton called the neutrino. It meets all the qualifications. Neutrinos are as numerous as photons, but have the ability to decouple earlier, about one second after the Big Bang. They rarely interact, thus are "invisible." The neutrino could supply the missing mass, and also provide gravity a head start in forming pancakes. But to be of any use, the neutrino must have mass.

In 1980, Valentin Lubimov, Evgeny Tretyakov, and their colleagues at the Institute of Experimental and Theoretical Physics in Moscow found a minuscule value for the mass for the neutrino in the range Zel'dovich needed. They have since refined the measurements; unfortunately, other experiments to measure a neutrino's mass have not been successful. Particle theorists say there is no reason why neutrinos should not have mass, and in fact, mass might better fit the symmetry of their theories. As one theorist remarked, "Mass would be prettier."

Meanwhile, in late 1983, Marc Davis, Carlos Frank, and Simon White of Berkeley; Adrian Melott of the University of Pittsburgh, and Joan Centrella of the University of Illinois — working independently — used computers to simulate evolution of a universe dominated by neutrinos. (See "Cosmology on a Computer," June and July 1983, ASTRONOMY.) In both sets of simulations, pancakes collapsed into filaments and fragmented into clusters. But they also predict that galaxies will begin to form in the present.



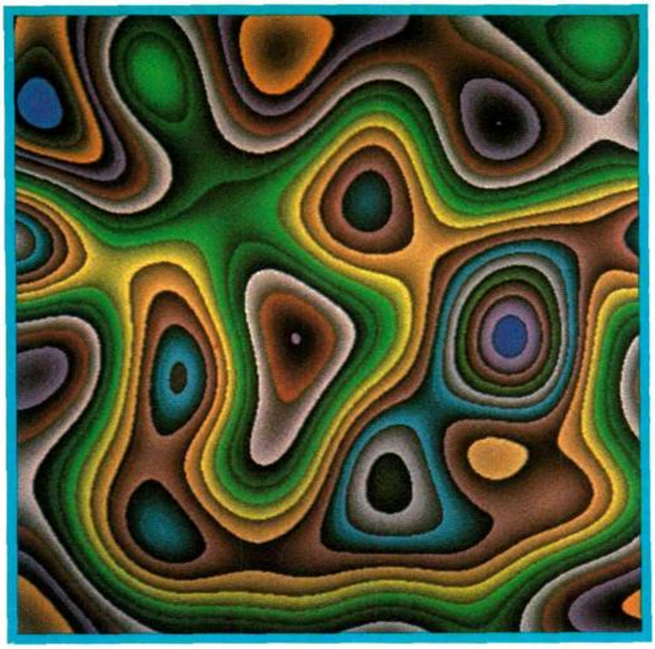
Assisted by a background of low-mass neutrinos, galaxies and clusters of galaxies condense into chains spanning millions of light-years in a computer-model universe. Curves enclose regions having double the average density. Courtesy of Adrian Melott, University of Pittsburgh.

So the pancake theory still miscalculates the age of galaxies. "Zel'dovich's grand filamentary scheme probably isn't true," said John Huchra. "It's more complicated than that."

One complication has been a refinement of the Big Bang theory, called the inflationary universe. In 1980, Alan Guth of MIT, and later, in 1982, Paul Steinhardt of the University of Pennsylvania, proposed theories which have revised our understanding of the first instants of the Big Bang. These propose that the earliest universe, when expanding and cooling, entered a peculiar state in which all matter and energy was "hidden" in a vacuum. The universe then inflated exponentially, and at the end of inflation, energy trapped in the vacuum was released and reappeared as matter and radiation.

Melott and Davis, working with White, Frank, and George Efstathiou, are currently using these predictions of the new inflationary universe to run further computer simulations. They replace the neutrino with any one of several particles, collectively called "cold, dark matter." Three replacement candidates have been found: photinos, gravitinos and axions. All exist only in particle physics theory, which explicitly predicts their mass. They are free to clump earlier than the neutrino, and much earlier than matter would at photon decoupling. Once again, the idea is that after decoupling, matter would have been free to follow these much larger tracks.

The computer simulations show a universe evolving



Computer simulation allows astronomers to recreate the early universe. Color contours correspond to the density of matter. Galaxies and clusters of galaxies form from such primordial lumps. Simulation by S. Djorgovski of the University of California at Berkeley, based on the work of Zel'dovich, and Silk and Szalay.

more or less as a combination of the top-down and bottom-up theories. Structure begins small; with gravitinos, the first things formed are galaxy-sized; with axions, even smaller. But the structure grows rapidly and large scale structures form quickly.

This cold, dark matter model seems successful; simulations produce the observed filaments and voids, and have galaxies forming at the correct times. The cold, dark particles are the "current best bet," Marc Davis says. "They have tremendous promise."

But one problem, according to Davis, is that the model needs to be tested with more particles. This would mean million-hour runs at current computer speeds. A more serious problem is that particle physicists haven't a shred of evidence for existence of the particles.

Contradictions continue to accumulate: the three degree background is too smooth to generate decent-sized fluctuations; random processes couldn't have built seeds that would form galaxies at all. Galaxies, being older than clusters and superclusters, formed first. But galaxy-sized seeds take longer than the age of the universe to develop into their present structure, and supercluster-sized seeds do not break into galaxies fast enough. In addition, supercluster-sized seeds formed by neutrinos before photon decoupling have the same problem, but neutrinos may not have mass. Galaxy-sized seeds formed by various dark particles earlier than neutrino decoupling grow into structure at the correct times, but the dark particles may or may not exist.

Large-scale structure, says Davis, "is running out of alternatives." Superclusters are surely real, but whether they are filamentary is now arguable. At present, the Center for Astrophysics catalog includes redshifts of 14,000 galaxies. Huchra no longer sees evidence for filaments because some superclusters are elongated and some are rounded. He notes, "It's a large sea with many kinds of fish." Davis asserts the shapes are linear; they appear as sausages, footballs, and pancakes, typically having a ratio between the long and short axes of 4:1. Certainly, says Davis, our local supercluster is linear. Rivolo says, "The only real data we have is on our local supercluster, and it's pretty spherical, a little squashed in the middle, certainly not a pancake, certainly not a filament." "One doesn't know for sure," says Neta Bahcall. She sees neither spheres nor filaments; she describes most shapes as amorphous and slightly elongated. "If we don't see filaments in Bahcall's work," says Peebles, "we *won't* see them."

In January of 1984, Jack Burns and David Batusky of the University of New Mexico at Albuquerque reported a filament running through Pisces and Cetus, a structure some 600 million light-years long. "I'm not going to say it's real," says Batusky, "but the redshifts of the clusters line up like beads on a string. These things look pretty real."

Part of the reason for disagreement is perceptual. "It's too easy for your eye to connect the dots," says Davis. The tendency of our eyes to create patterns out of points is called the "martian canal effect." For years, the more imaginative astronomers believed the surface markings on Mars were canals; Percival Lowell even envisioned a martian civilization which irrigated its deserts with water from polar ice caps via canals. "Many effects can make things look filamentary," says Rivolo. "You see filaments in two dimensions, so looking in three, you see confirmation."

Another reason for disagreement is the lack of data. Astronomers are in the same situation experienced by geographers in the 14th century: their maps give preference to the nearby and familiar. Quasars (the farthest known things dating near the beginning of time) have not been systematically mapped. Most galaxies are too faint for their redshifts to be taken. Redshift data on clusters of galaxies concentrate on the near and rich. Redshifts of many clusters are based on measurements of one or two constituent galaxies. Bahcall used redshifts that cover about 10 percent of the volume of the universe. Peebles and Huchra think that sample is fair, while Rivolo suspects the structure might change by measuring more and deeper redshifts.

What about the future? Astronomers will consider more theoretical alternatives. Maybe the inflationary universe theory is wrong. Maybe effects other than gravity — like explosions — could have formed particular seeds in the earliest universe. "Maybe the best we can do," says Davis, "is find a consistent model." Observationally, astronomers will work to obtain more data, including farther and fainter redshifts on as many galaxies as possible, and redshifts on more quasars. "We hope to get to a regime where the universe starts to smooth out," says Huchra.

"Of course the main excitement," Peebles wrote in a recent issue of *Science*, "will be the search for the largest possible things — holes, or lines, or sheets that might be fossils of something interesting."

Barry Parker teaches physics at Idaho State University and has recently published a textbook, Concepts of the Cosmos. *Ann Finkbeiner is a Baltimore freelance writer with an active interest in cosmology.*

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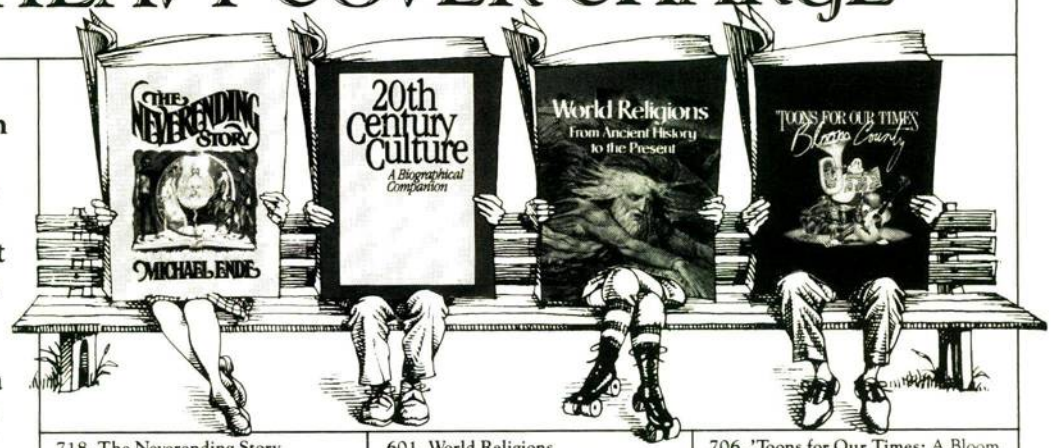

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Amateurs from all over the country experienced typically midwestern summer weather August 1 through 4, for tours and observing at the joint national convention of the Astronomical League, the Association of Lunar and Planetary Observers, the National Deep Sky Observers Society, and the International Amateur and Professional Photoelectric Photometers. This 38th Convention of the Astronomical League gathered at Carroll College in Waukesha, Wisconsin. It was locally sponsored by the Milwaukee Astronomical Society.

A few days after the convention, we at ASTRONOMY sat down to discuss ALCON '84 and our impressions. Here's what we said:

Richard: Well, now it's over. What do you think of amateur astronomers?

Debbie: My first and lasting impression of ALCON was the enthusiasm of the amateurs, from the littlést toddler to the senior attendees. I saw representatives of every aspect of amateur astronomy — from novices interested in buying a basic star chart, to the seasoned veterans fascinated by photoelectric photometry. I also met several excited telescope builders looking for bargain mirrors at the swap meet, and the proud builder of that fantastic open-frame Dobsonian telescope on display across from our booth.

Bob: It was gratifying, too, to have a large turnout at ASTRONOMY's open house. Our contact with readers usually involves the post office as a mediary, so the open house provided a welcome change of pace. Kristie, Susan, and I enjoyed spending the greater part of an afternoon showing people how we go about putting an issue together and answering questions about the inner workings of our publishing company.

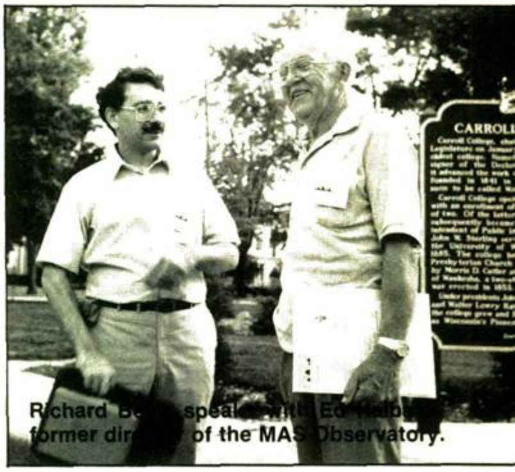
Kate: The group who came to visit ASTRONOMY's offices was delightful. Their levels of knowledge about astronomy were mixed, and several people gave me the impression they'd like things to be presented at a very elementary level. One woman told me that our articles often go from A to C, assuming that she already knows B when she doesn't. Often beginners have to struggle their way into the hobby, searching for articles that will explain what they don't understand.

Richard: Did anything particularly surprise you?

Susan: The big surprise for me was when we took the tour down to the stockroom. It's not very nice-looking — well, it's a stockroom! — but everyone caught buying fever. Everything we had — books, posters, back issues, old calendars, subscriptions, and patches — all were eagerly examined and purchased. I only wish we could have displayed everything as it would be displayed in a store, although that's what our ads try to do each month in the magazine.

Dana-Lynne: At AstroMart, I was surprised by how fast the excitement built as the scopes were set up. There were all sizes and types, plus telescope accessories, astrophotography equipment, astronomical books, posters, T-shirts, and astronomical novelties. They filled the room from corner to corner. Some of the exhibitors were unable to attend all four days, but there was plenty to see and buy on any given day.

Dave: The most curious thing about ALCON was hearing thoughts and opinions from such a wide spectrum of people. On the trip down to Yerkes Observatory, I sat in the back seat of a car with a physician from Michigan, a woman accountant from Chicago, a part-time astronomer and writer from Tucson, and a geologist from Kentucky. And here I was, an editor from Milwaukee, Wisconsin. I can't forget thinking, "This is really neat — these people are my friends and I don't have anything to do with what they do, except have a love for the stars!"



Richard B[illegible] speaks with Ed Halb[illegible] former director of the MAS Observatory.

Kristie: ALCON was my first opportunity to meet some of our subscribers — I didn't think they'd have much patience to listen to the business end of publishing, but I was wrong. What surprised me was how easily they grasped what I try to do as circulation director; they even understood the pitfalls of advanced scheduling. They were very polite, but weren't at all shy — one woman quietly demanded an explanation of our "Free Star Map" headline.

Richard: So you got lots of questions?

Kristie: Oh yes. One banker/astronomer even asked about our bounced check rate. I was happy to report our subscribers are a good bunch; less than one percent send us bum checks.

Susan: The number of people who showed up for our open house on Thursday afternoon surprised me. We

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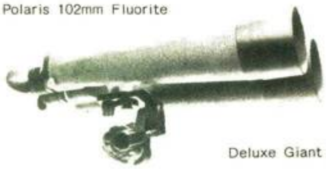

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split the group, which was somewhat bigger than we'd expected, into two smaller groups. One group started off with the editorial and production of ASTRONOMY, while the other heard the history, business aspects, and marketing strategies behind our magazines and products.

Richard: Did you hear any complaints?

Kristie: Several club presidents and treasurers expressed frustration with our club renewal procedures. I found out members have been receiving notices that only the club treasurers were supposed to receive. Sigh! I do try, but we'll have to tighten up that procedure. They all agreed, though, that you can't beat our club subscription rate — $12.

Richard: This year's ALCON theme was "Astronomy: the Amateur Science." Many of the papers, especially those at the ALPO and IAPPP sessions, were pretty serious stuff. Did any of you get a sense of how the attendees responded to those talks?

Kate: I met an "aesthetic astronomer" — that's Ken Fulton's term — who was almost apologetic about the fact that even though he likes to observe, he doesn't want to get involved in learning the "scientific stuff" or do any "serious work."

Dave: Although I spent much of the time simply talking to observers, the ALCON talks offered a wide spectrum of information for amateur astronomers. I think a lot of them learned a lot. Don Parker spoke on planetary astronomy for amateurs. His photos are superb — they've appeared in ASTRONOMY for years — and the torrent of information he delivered with them formed a basis for what amateurs can do in planetary astronomy.

Richard: Don's delight in what he's doing is so obvious that he's a pleasure to hear. There's no mystery why people "get serious" about astronomy — they really enjoy it.

Robert: During the last few years, I've drifted away from seeing myself as an "amateur-professional" astronomer, although there was a time when this feeling motivated me pretty strongly. Yet listening to the papers at ALCON, I found myself attracted to it all over again — more than I would have thought! Conventions like this are terrifically energizing. I came away with a renewed sense of purpose and a desire to do more than simply look at the sky with a telescope. I'd say that even the most determined "aesthetic" astronomer couldn't have attended ALCON without catching some of this.

Kate: I was disappointed with the poor showing of amateur telescopes and astrophotos in the student union. I guess I expected more, and maybe I've been spoiled by the number and quality of photo submissions we receive here at the office.

Richard: Quite a few more telescopes showed up on telescope contest day. I think many people didn't feel comfortable leaving their scope sitting in the student union building several days running.

Dave: Jack Marling had lots of photos — in fact, he must have set some sort of record for presentations at an astronomy conference. He gave four talks, each accompanied by color photos of galaxies and nebulae.

Richard: Did anyone do any observing? It wasn't very clear. . . .

Dave: In midweek during the middle of the night, I got a phone call about the new comet that had just been discovered. Ironically, the most noteworthy feature of Alan Goldstein's and my talk on deep-sky observing, given early the next morning, was an announcement to the convention that Comet Takamizawa was sweeping through northern Capricornus.

Richard: Gerry Samolyk, the MAS observatory director, showed us the very first pictures taken with their new 25-inch telescope. By the way, the Milwaukee group did a terrific job in completing the new scope on time for ALCON. It had been in the works for years.

Dave: Oh, yeah. On Saturday night, the last night of the convention, I went out there with Alan Goldstein, Jack Marling, Bryan Shumaker, Tom Burns, and John Kerns. The skies weren't terrific, but we saw the Ring Nebula through the 25-incher. Its form was well-defined, but you couldn't see the central star. Outside, among the dozens of telescopes ALCON people had set up, we spotted the eighth-magnitude nova in Vulpecula which had been discovered just four days before.

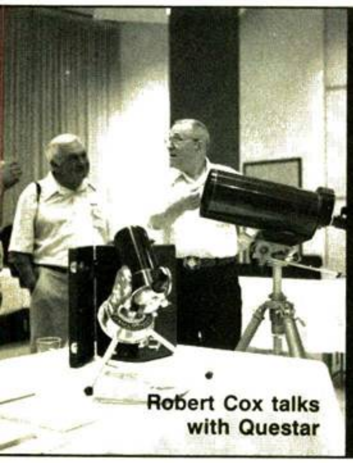
Richard: Dana-Lynne, as the organizer of AstroMart'84, how did it go?

Dana-Lynne: AstroMart '84 was attended by over 400 ALCON '84 participants, as well as people just checking over or shopping for equipment. Our display area was spacious, well-lighted, air-conditioned — just about perfect. Of course, we lured people in with donuts and coffee, too! Altogether, I'd say it was a resounding success.

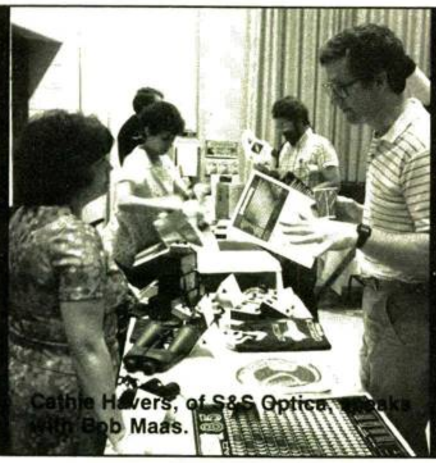
Robert: Since I'm one of those amateur astronomers who doesn't join clubs or hang around with lots of other amateurs, I don't get a chance to look over the latest in equipment very often. For that reason alone, I enjoyed browsing through the AstroMart displays. They, and the people I met there, made up fully half the meeting as far as I was concerned.

Kate: I was impressed with the group's interest and need for astronomical books and other items. These aren't generally available, and it's evident to me that we really do provide a significant service in offering them to our readers.

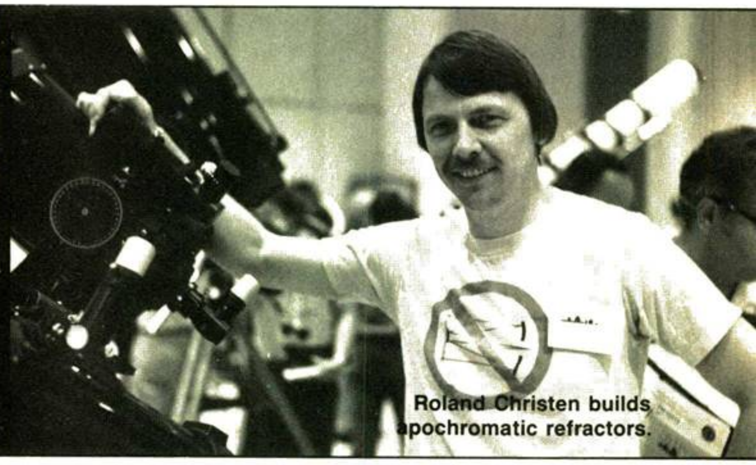
Robert: For the most part, general



Robert Cox talks with Questar



Cathie Havers, of S&S Optica, speaks with Bob Maas.



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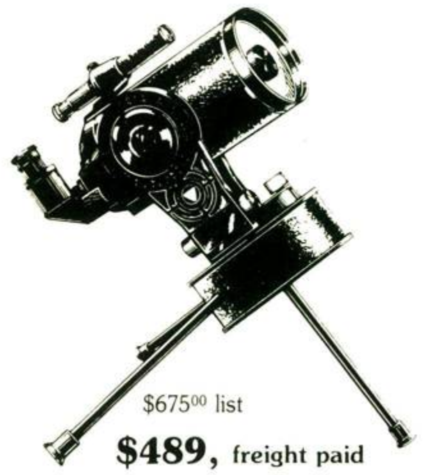

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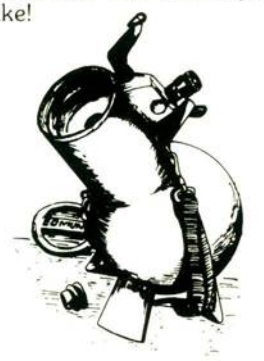

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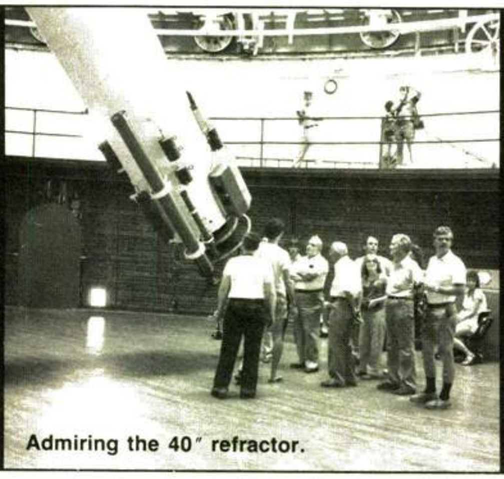
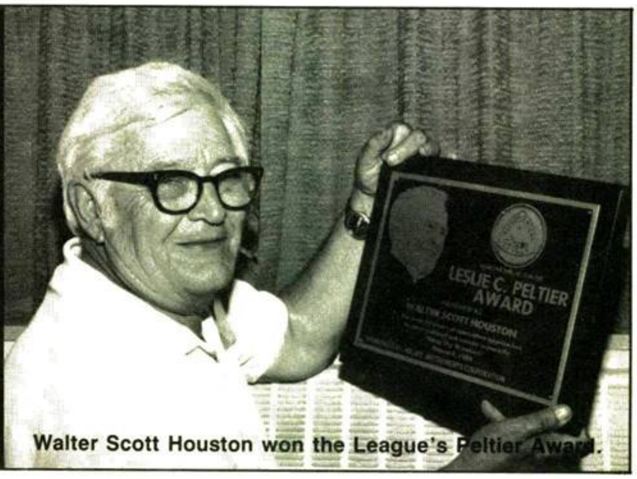


Admiring the 40″ refractor.



Walter Scott Houston won the League's Peltier Award.

bookstores have awfully meager selections of astro books and many public libraries aren't much better. Working for the magazine, I see just about every astronomy book that comes out, but I remember what it was like to haunt the local bookshops, hoping each visit would turn up a new title.

Pat: Lots of the ALCON people made a point of coming by every time they were downstairs and talking to me. Often two or three would be discussing the Sky Atlas, the Burnham's handbook set, or other items — how great they were to use and what a bargain they were at these prices. Several other people would be listening — including me — so that when someone else came up and wanted to know about a certain item, I could answer their question with more confidence. There were several people who, being very knowledgeable, brought others to the table who were new to astronomy and showed them books to help them.

Robert: Mingling with the crowds in the display area was a lot of fun. I found out one thing quickly — if you ever want to meet people, just carry an old camera! I took my 1951 Rolleiflex TLR to photograph the meeting and there must have been two dozen people who come up at one time or another and told me how they'd once used one just like it. The conversation about "golden-oldie" cameras eventually switched to telescopes, eyepieces, favorite observing manuals, or whatever. I especially liked getting to meet the people who have been just names on a manuscript or photograph up 'til now — and I talked to several who promised to write something for us.

Richard: What do you think impressed the amateurs who visited ASTRONOMY?

Kristie: Their eyes lit up when they saw our storeroom filled with patches, posters, books, and back issues. Since we're not a retail store, we did struggle a little finding change for $50 and $100 travelers' checks — Rosie [Pickart] even dug through her purse looking for change.

Debbie: ALCON was a chance for astronomy amateurs to meet their stars — the famous amateurs such as Walter Scott Houston or Bob Cox. I was fascinated by the young teenagers who were thrilled to get Richard's or Robert's autograph. The attendees were as happy as children in a candy store, as they rubbed shoulders with our editors, or bought the latest books and eyepieces and observing aids from the sellers at AstroMart.

Dave: Most of the people who get ASTRONOMY were amazed that the magazine, when it is "finished" and leaves our office, consists of a stack of cardboard sheets with type pasted down and a pile of photos sitting on top. A lot of the production "magic," which makes the colors come out looking right, happens at the film house and the printer's. We have a good idea of how things will look, but we're always a bit surprised at the result ourselves!

Richard: How would you sum it all up?

Kate: It was good to meet some of our contributors. I've known a lot of these people for a long time now, but only through letters.

Dave: During the first week of August, AstroMedia was under siege. A demolition crew was dynamiting a section of elevated freeway only 40 yards from our front door — and we lost half our front windows! We had lots of work to do on the November ASTRONOMY and the fall issues of *Deep Sky* and *Telescope Making*. We soon learned that with 400 amateur astronomers in town, it wasn't a week for getting work done. It was a week for surviving.

Pat: I think there were several reasons for our success in selling at ALCON. I had been given some of our best books to sell at good sale prices. Like Robert said, they were extremely pleased to see what the books we offer look like and to browse through them at their leisure. We were right next to the coffee and donut table. I didn't push people to buy and I think that might have helped.

Debbie: Many of the types of amateurs that Ken Fulton talks about in *The Light-Hearted Astronomer* were right there at the convention. I saw the amateur who builds telescopes but who never looked through one, and I saw the amateur who buys every new gadget available on the market. But mostly I saw the concerned and dedicated amateur — the one who has put in his years of study and has reaped the rewards that amateur astronomy has to offer. It was an inspiring convention.

Dana-Lynne: Not being an astronomer myself (I'm embarrassed to say), I was initially pretty apprehensive about meeting all these serious amateurs. My fears were quickly put to rest by their down-to-earth friendliness — despite where their heads were at!

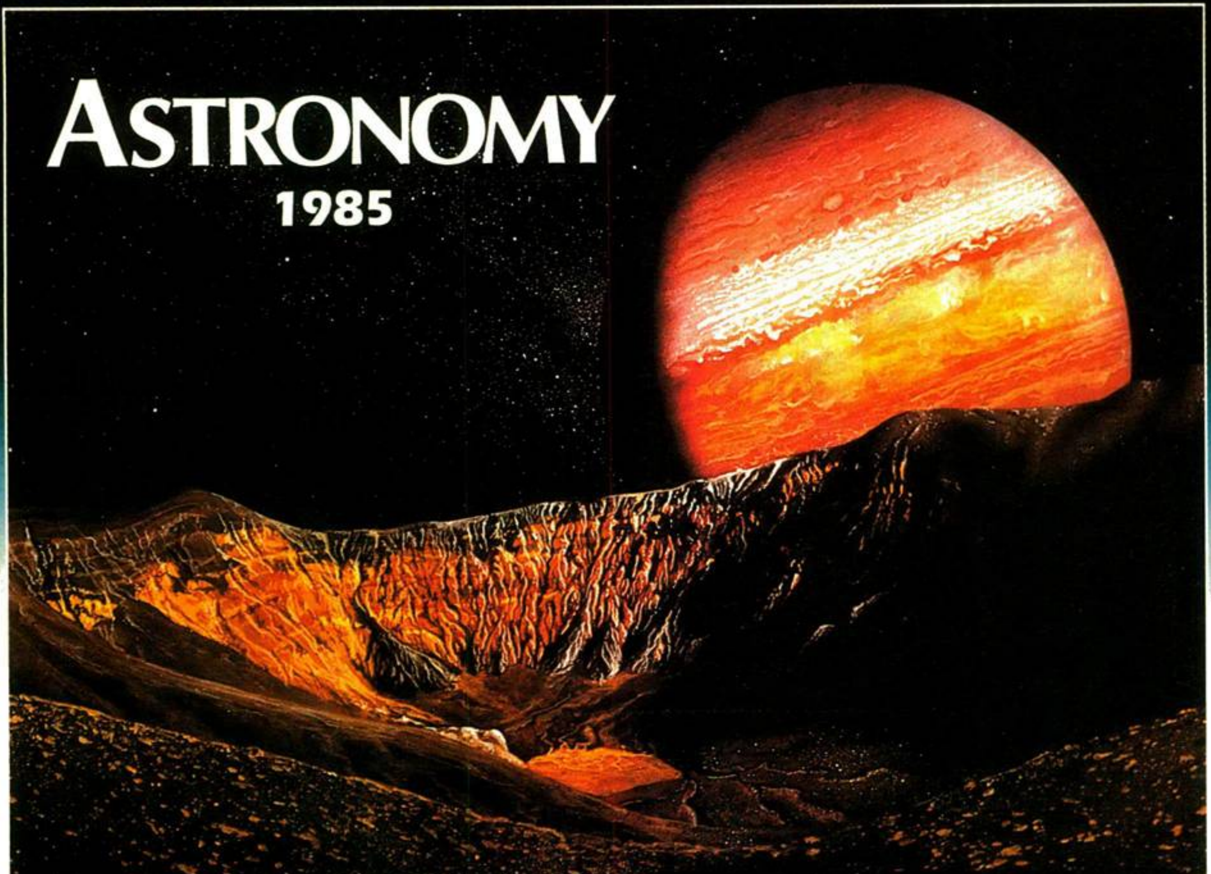
Pat: It was fun. I appreciated the chance to go.

Debbie: I can't wait until the next amateur astronomy convention.

Susan: I plugged all our new products: the 1985 ASTRONOMY calendar, *The Star Book*, and *The Light-Hearted Astronomer*. Watch for them — coming soon to a store near you!

Dana-Lynne: Bob, how would you feel about sending me to ALCON '85 next year in Tucson?

— Pat Adams, Richard Berry,
Kate Bond, Robert Burnham,
Dave Eicher, Kristie Fischer,
Bob Maas, Susan Poole,
Dana-Lynne Terry,
Debbie Wicentowski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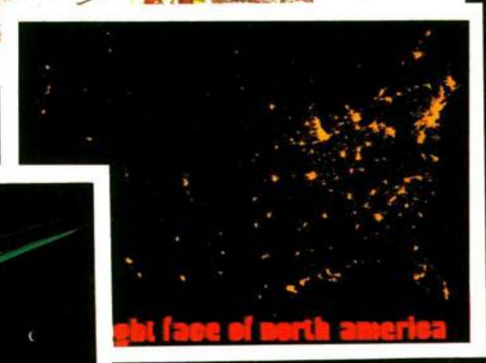

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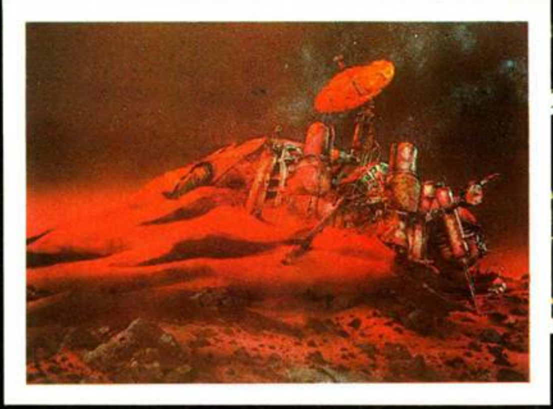

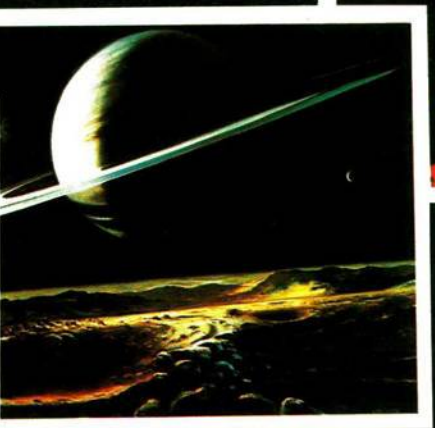

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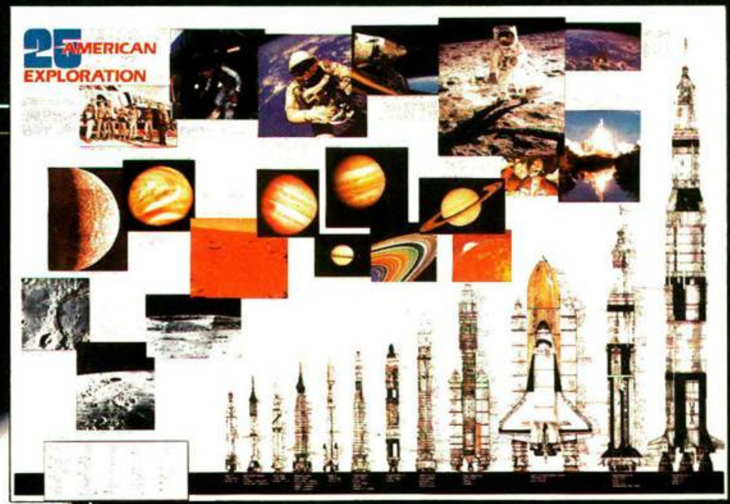

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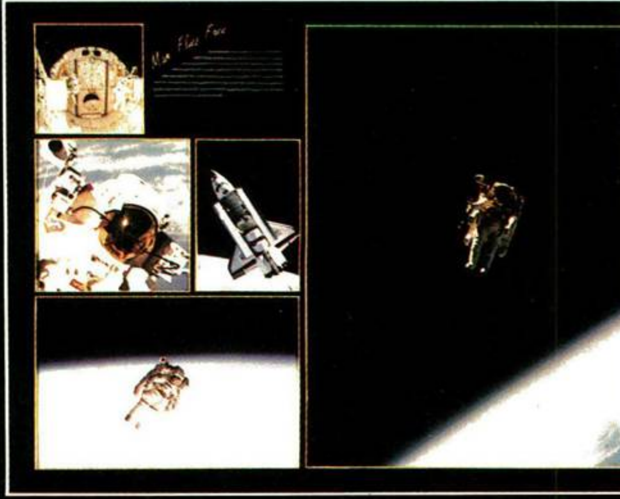

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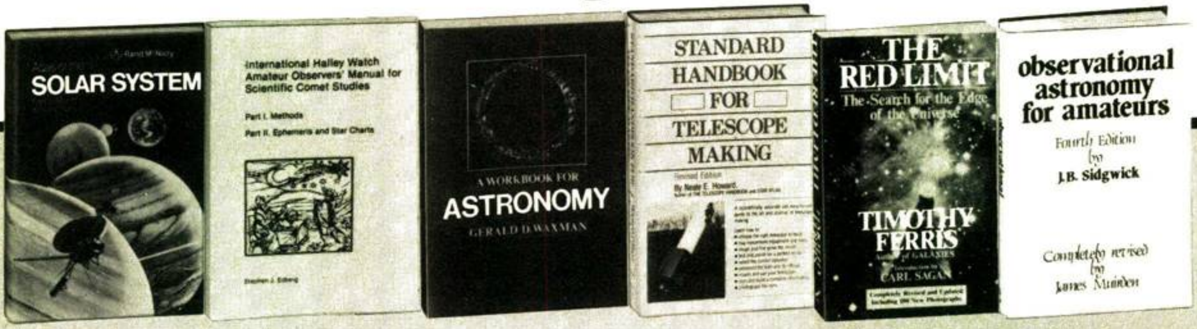

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ASTRONOMY
In Focus

Star-Struck with VR1000

Sir / Having read the review of VR1000 film in the July issue of your splendid magazine, I thought I'd share my delight of the film with you.

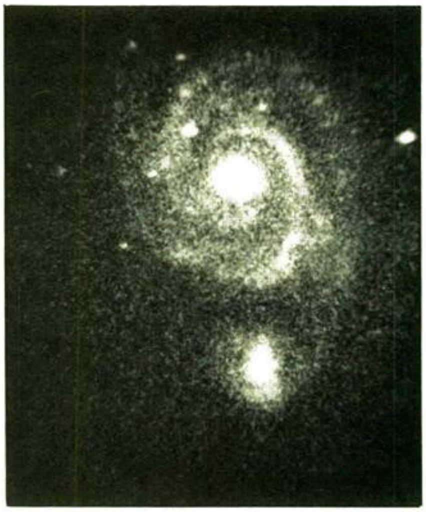
By working evenings after school a couple of years ago, I finally collected enough money to replace my 3-inch alt-azimuth refractor for a second-hand 8-inch SCT corrector and off-axis guiding system. It had an awful wedge that was nearly impossible to polar align, so I stuck to photographing the Moon and planets — with great success, I might add. I made one attempt at deep-sky photography with Fuji 400 film, but after spending the best part of two hours polar aligning, I was still constantly correcting. The resulting picture of M-31, after a 40-minute exposure, was pretty pathetic.

Last summer, I had the wedge modified for easy polar alignment. Inspired by the introduction of VR1000 film, I thought I'd try once more to get photos that resembled something I'd seen in books. Unfortunately, by the time my wedge was returned I had to return to university, so my attempt at deep-sky photography had to wait until last Christmas.

After two weeks of awful weather, the week before I returned to university was relatively clear with subzero frosts. Polar alignment took a couple of minutes and I was soon ready to go. There was still the problem of light pollution (I live in a large suburban town, 10 miles north of Greater London), so I decided to photograph M-51 directly overhead in the darkest part of the sky. I guided on it for one hour at −3°C, which wasn't much fun, and I began to ask myself, "Is it all worth it?" Memories came back of my attempts to photograph M-31 with 400 film only to find that after two 40-minute exposures, I had left the camera shutter on $\frac{1}{125}$ second!

The next night I tried M-42 with a 15-minute exposure and then packed up for my return trip to London. To beat the light pollution, both exposures were shot at f/10 (with VR1000 print film); I used an ordinary SLR without any filters. I must say, I wasn't too optimistic when I left the film to be processed (not printed).

When I got the negatives back, though, I really could not believe my eyes! There was that beautiful spiral M-51 and its companion galaxy showing structure I wouldn't have believed possible to get with an 8-inch telescope. From that day on, I have been a devoted deep-sky photographer. Getting a photograph like that — when visually I could see no detail at all — made it worth the torture of guiding for an hour in subzero temperatures.



I took the M-51 and M-42 shot in to be handprinted (costing about £16 for the pair of 8" x 10" prints) and was again overjoyed with the results. I was, however, a bit disappointed with the film grain that was visible.

At Easter, I photographed M-13 (and the nearby galaxy NGC-6207), M-57, M-81, M-82, and M-27 with equally good results. To cap it all, my guiding turned out to be not so bad.

Anyway, last week I copied the handprinted prints with a new close-up lens I had just bought. Seeing how blue M-51 was with the sky grain mostly brown and black, I copied the galaxy in blue light, slightly underexposing to darken the background sky as much as possible and to bring the galactic detail out of the grain. Well, it worked better than I would have imagined. I have enclosed one of these copies — clearly there is still a lot of grain visible — but just look at the detail in the arms of M-51. That picture was taken in light-polluted skies with a plain old 8-inch scope using an SLR and VR1000!

As soon as the nights get longer again, I can't wait to get back in the garden with telescope, camera, and some of the new Fuji 1600. All I can say is, "Thank you" to Kodak for the film and to ASTRONOMY for the inspiration. One day, I hope I'll be able to produce photographs of the quality taken by people such as Jack Newton, but with VR1000 that day shouldn't be too far off for a whole lot of people.

Thanks again for the magazine.

Ray Emson
Hertfordshire, England

Astronomical Crackpots

Sir / Thank you for the May AstroNews story on the creationist attack on astronomy. Most of the public is unaware of what crackpots the creationists really are. Henry Morris, the director of the Institute for Creation Research and author of numerous "science" textbooks, has written some very bizarre things pertaining to astronomy. For example, in his book, *The Remarkable Birth of Planet Earth*, Morris makes the claim that the craters of the Moon and the rings of Saturn are the result of fights between good and bad angels.

I urge all interested citizens and scientists to get involved. We cannot let fundamentalists wreck science education in this country with pseudoscientific fantasies. To counter the creationists, a citizens' group known as the Committees of Correspondence has been formed. Readers of ASTRONOMY who are interested in joining their state's Committee of Correspondence should write to the National Center for Science Education, Box 32, Concord College, Athens, West Virginia 24712.

Daniel J. Phelps
Lexington, KY

British Amateur Astronomy Centre

Sir / I write to ask that you tell the world about a marvelous astro project that is well under way here in the U.K.

I refer to the Amateur Astronomy Centre. This is an undertaking that is organized and sponsored by several British astro instrument makers/distributors having several famous (in the U.K.) members, e.g. Dudley Fuller, Patrick Moore, Heather Couper, etc.

The observatory site is in a basin high on the Yorkshire/Lancashire moors. The nearest sizable town is Rochdale, eight miles away. When complete, the centre will comprise a 40-inch reflector (already nearly finished), a 30-inch reflector, a 17-inch reflector, many smaller telescopes, a planetarium, and library.

I am very pleased that such a bold attempt to spark amateur astronomical involvement is under way, and I am proud to be a founder member (membership fee — £2.50).

Barry J. Cane
Manchester, England

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Automated Astronomy III

Sir / Thank you for printing my letter (June 1984) in response to Russell Genet's letter (February 1984). As a result I have met Louis Boyd. Although he never hinted at it, it *was* rude of me to be so intolerant of any individual who derives pleasure from astronomical observations. As Mr. Boyd pointed out, he and other members of IAPPP have introduced the computer to the wonders of the heavens. Now *that's* a perspective I hadn't considered.

It is obvious that Louis Boyd, Russell Genet, and others are justifiably proud of their accomplishments in the field of photoelectric photometry. They are to be congratulated for their dedication and innovation, as is ASTRONOMY magazine for giving them the credit they deserve.

As a dedicated visual observer and dabbler in astrophotography — and, incidentally, one whose wife cannot understand how it is possible to look at M-42 simultaneously through three telescopes and two pairs of binoculars for six consecutive hours, several consecutive days in a row — I think I may have lost track, during the few minutes it took to write that letter, of one very important thing. Astronomy is a field so limitless in scope that there is plenty of room for professionals, serious amateurs (like Louis Boyd and Russell Genet), and deep-sky observers (like myself). There is also plenty of room left over for anyone who enjoys the wonders of the night sky, *however* they enjoy it.

So I promise I won't wake Mr. Boyd up in the wee hours of the night, although he's welcome to drop over and wake *me* up on Saturday or Sunday mornings. Intolerance has its just desserts.

Jan M. Owen
Phoenix, AZ

Just to Clarify Matters . . .

Sir / *The Hitch-Hiker's Guide to the Galaxy* clearly states that the answer to "life, the universe, and everything" is 42, not 46. I am referring, of course, to your July 1984 letters page.

I couldn't let such an important error pass unnoticed!

Martin Jackson
Camberley, Surrey, England

Ooops!

The photo on page 76 of the September issue was taken by Frank Zullo.

Behind the Scenes

Grasping the New Cosmology

This month ASTRONOMY devotes considerable space to mind-bending particulars of the new cosmologies — "missing mass," supergravity, gravitinos, GUT, our 11-dimensional universe — concepts which I have been warned are, quite frankly, so weird as to be virtually unthinkable. We thought long and hard about how to present these ideas, and, for that matter, whether we should at all. Ultimately, we decided that ASTRONOMY readers would be interested — and, well, here we are.

I do have a tip for the reader, however; a technique I have found valuable in working with these stories. When it all seems impossibly involved, go outside and look at the stars. Remember that what you're reading is not the fairy-tale fantasies of mad scientists, but humankind's best efforts to understand what's there — and here — right now. We're it — monopoles and all — here and now. Nothing about the universe will change if you read these articles, except that you will perhaps gain humble insight into the incredible mechanism the cosmos is. So with that, please read and enjoy.

On a completely different note, AstroMedia is pleased to announce that American Public Radio now distributes *Sky Report* nationwide. Produced by Frank Reddy, an Assistant Editor at ASTRONOMY, and WUWM Radio here in Milwaukee, these two-minute radio spots are designed, as Frank says, "to get average people to look at the sky once in a while." If you'd like to hear *Sky Report* in your area, bug your local Public Radio station.

Finally, we're pleased to have assisted the Astronomical League and its members with ALCON '84 by sponsoring AstroMart '84 this year. As a side benefit, many of our non-astronomical staff members had a chance to meet real, genuine, amateur astronomers for the first time. We present their reactions in our report on ALCON in this month's FORUM.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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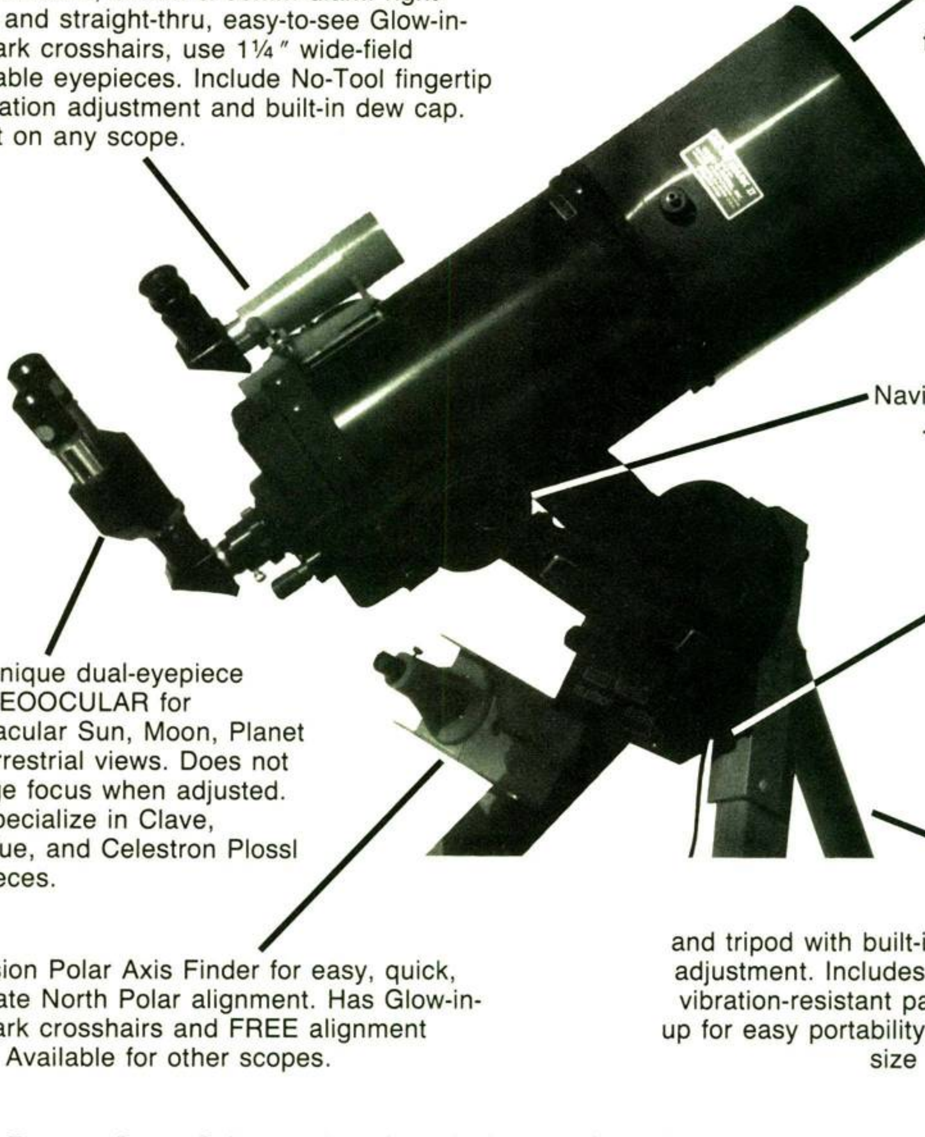

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Observing the Local Group of Galaxies

Gazer's Gazette

Of the roughly 6,000 bright galaxies in the sky, 27 share a common bond. They are members of our Local Group of galaxies — a cluster of galaxies united by their mutual gravity. The Local Group represents our extragalactic neighborhood; the cluster measures some 2.0 x 1.5 megaparsecs and is a fairly typical group of galaxies. The local group is loosely structured, no richer in the center than at its edges, and contains mostly moderately wound, Sb-type spirals and their little elliptical companions.

The two largest spirals are our Milky Way and M-31, the Andromeda Galaxy. Between them, these two contain much of the Local Group's material — perhaps 60 percent of the total. The remaining galaxies — the "pinwheel" spiral M-33 in Triangulum, the Magellanic Clouds, the heavily obscured lenticular galaxy Maffei 1, and the many dwarf elliptical systems — contribute the rest.

Local Group members range from the brightest galaxies in the sky down to some of the most challenging low-surface-brightness objects. The bright members are not only easy to find, but under dark skies they show detail in larger backyard telescopes. With the fainter systems — many of which are best viewed in the springtime — even finding them can be a real challenge.

The Andromeda Group

Let's start with the biggest — M-31 (NGC-224) — the Andromeda Galaxy. Easy to find, just 1° west of the star Nu (*ν*) Andromedae and shining at magnitude 3.5, the Andromeda Galaxy looks like a fuzzy, elongated patch of milky light some 3° across. The current value for M-31's distance is 760 kiloparsecs, making it the most distant object visible to the naked eye.

The Magellanic Clouds, Large (at top) and Small (bottom) are the Milky Way's satellite galaxies. Located far down in the southern sky, these galaxies are best visible during the southern hemisphere's summer months (October through February). Ron Royer photo.

Through binoculars, the galaxy begins to show its stuff. Under a good, transparent sky, 7 x 50s reveal a pale off-white oval core, and a subtle surrounding mist of grayish-green nebulosity. This "mist" is, of course, the combined light of millions of unresolved stars tucked in the galaxy's spiral arms. On a night when conditions are good, and you're relaxed, train your telescope on M-31. Scopes with an aperture of 6-inches or more should reveal two prominent dust lanes which separate the arms. Since the galaxy measures 178′ x 63′, stick to low powers and follow the galaxy's structure outward from the nucleus. An 8-inch scope is all you need to spot NGC-206 — a huge starcloud residing near the southern tip of M-31's western edge. This clump of stars appears as a bright condensation against the fainter background nebulosity, and measures 900 parsecs across — larger than some of the ellipticals locked into orbit around M-31.

Large amateur telescopes — in the 12-inch to 20-inch range — deliver a bright, stunning image of M-31's core and spiral arms. If the sky is dark and transparent, put a high-power eyepiece into your scope and center it on M-31's core: you'll see a sharp, starlike knot representing its innermost kiloparsec. With a scope of at least 12-inches' aperture and a large-image-scale finder chart, you can even observe a few dozen of M-31's brightest globular clusters — visible as tiny "field stars." (Such a finder chart appears in the fall issue of AstroMedia's *Deep Sky* magazine.)

As you'll probably notice by observing the Andromeda Galaxy at low powers, two small satellite galaxies accompany it in a low-power field. These are M-32 (NGC-221) and NGC-205, both ellipticals which orbit the big spiral at distances of five and seven kiloparsecs, respectively. Through the eyepiece, M-32 lies about 24′ south of M-31's core, and NGC-205 about 35′ northwest. Here is a classic example of differing surface brightness: the two little galaxies have nearly the same total magnitude, but at 17′ x 10′, NGC-205 is more spread out and appears much fainter than 8′ x 6′ M-32. If we rate them by magnitudes per square arc-minute, we find that M-32 has an average surface brightness of 12.3, M-31's outer spiral arms are 13.4, and NGC-205 measures in at 13.6.

Two other small elliptical galaxies are bound by the gravitational tug of M-31, but are much farther away: NGC-147 and NGC-185 lie some 90 kiloparsecs from M-31's core. They lie some 7° away on the sky, high up in the constellation Cassiopeia. Both have a very low surface brightness: NGC-147 at 14.5 and NGC-185 at 14.3. They also have large diameters — 12.9' x 8.1' for NGC-147 and 11.5' x 9.8' for NGC-185 — so you'll need a 6-inch rich-field telescope to detect either of them on a dark, moonless night. A 12-inch telescope at medium power shows an obvious oval shape to NGC-147, and reveals a slight increase in brightness toward the galaxy's center. Larger telescopes will enable you to spot what appears to be a foreground star positioned exactly in NGC-147's center; this is not a star, but the galaxy's nucleus.

NGC-185 is somewhat easier to detect. It has a more condensed and brighter center than that of NGC-147. A 10-inch reflector at low magnification provides a good look at the galaxy's smooth, subtle glow and fairly bright center. Several dark patches show up well in observatory photographs of NGC-185, and these might possibly be visible with large amateur telescopes under ideal conditions.

IC 10 and Maffei 1

Two additional Local Group members reside in Cassiopeia. The first is IC 10 — an irregular galaxy about 1.3 megaparsecs distant located near the outskirts of the Local Group. This galaxy is physically about the same size as NGC-147 and NGC-185, but is nearly twice as far away. Its published total magnitude of 10.3 and surface brightness of 13.5 sound good, but it is very difficult to find. Undoubtedly, were it located away from the dusty Milky Way, it would shine more brightly. With an 8-inch or larger telescope, use the lowest power eyepiece. Look about 2° east of the bright star Beta (β) Cassiopeiae; IC 10 galaxy may be visible as a soft, even halo of nebulosity.

The last galaxy in Cassiopeia is Maffei 1 — an infrared object discovered in 1968 by the Italian astronomer Paolo Maffei. Maffei 1 lies at a distance of 1.0 megaparsec and is probably a large, fairly massive lenticular galaxy. A problem in observing Maffei is the rich Cassiopeia Milky Way, which reddens and obscures its light. If Maffei 1 were located in Cetus, for example, it would shine at sixth magnitude and rival M-33 as one of the sky's great galaxies. As it stands, Maffei 1 is positioned between the Double Cluster and the huge emission nebulae IC 1805 and IC 1848, and has an average surface brightness of 19.6, making it virtually impossible to find. To further confuse matters, there is a little knot of stars located at this same position in the sky. If you're an astrophotographer, though, you can photograph this galaxy with a deep exposure of an hour or more.

The Triangulum Spiral

M-33 (NGC-598) in Triangulum is a grand example of a loosely wound type-Sc spiral. We see it almost face-on, providing us with a good look at its spiral structure. M-33 has a total magnitude of 5.7, placing it just within the limit for naked-eye objects under dark skies. M-33 has a reputation for being difficult, but it really isn't. The prime requirements for viewing it are a *dark* sky and a telescope that gives *low* magnification. Binoculars show that M-33 consists of a relatively bright core and pale outer halo, and wide-field telescopes in the 4-inch to 8-inch range reveal the spiral arms. These appear as a misty oval of light and measure some 62' x 39' in extent. Visible in M-33 — as with M-31 — are some good examples of detail: 10-inch scopes show the tiny stellar nucleus in the galaxy's core, and knotty brightenings and darkenings in the spiral arms. NGC-604 — the brightest feature in the arms — is an enormous HII region. Look for it to the northwest of the core, about 10' out. There are at least 80 emission nebulae known in M-33, but NGC-604 is by far the largest and brightest. It spans some 320 parsecs and contains enough material to make a dwarf galaxy of its own.

With a 17.5-inch telescope, blue-transmitting nebular filter and trained deep-sky eye, the knotty nature of M-33's spiral arms comes alive. Intricate filaments of dark structure intertwine with glowing starclouds, creating a ripple effect. The smooth pinwheel shape is readily apparent, and the arms extend outward by a Moon's diameter on either side of the nucleus.

Two Tiny Autumn Ellipticals

Another autumnal member of the Local Group is the so-called Sculptor System — a peculiar dwarf elliptical companion galaxy to the Milky Way some 110 kiloparsecs away in Sculptor. This large and dim galaxy resembles a globular cluster expanded to 50 times normal size. And it is extremely difficult to find despite a total blue magnitude of 9.0. The reason for this is that although the galaxy covers over one degree of sky, its star density and surface brightness are extremely low and the brightest stars in it glow at only 18th magnitude. Astrophotographers with suitable equipment, however, should still attempt to photograph it with a deep exposure of an hour or more.

When Harvard College Observatory astronomers discovered the Sculptor System, in 1938, they also uncovered a similar object in Fornax, which they cleverly dubbed the Fornax System. These two were the first dwarf elliptical galaxies to be found. Later, astronomers realized that such galaxies are probably abundant throughout the universe, although dim and difficult to detect beyond the Local Group. The Fornax System, like its cousin in Sculptor, is a difficult target for amateur telescope users. It also has a total blue magnitude of 9.0 and measures 20.0' x 13.8', giving it an average surface brightness of 15.1. To see this galaxy, you'll need a large telescope, a wide field eyepiece, and dark skies with excellent transparency — and then you may *just* detect it!

Ironically, a tiny piece of the Fornax System — a 13th magnitude globular cluster — *is* bright enough to see. Catalogued as NGC-1049, it lies just northeast of the galaxy's center and measures about 24 arc-seconds across. If you have a 6-inch or larger telescope, center its position in a wide-field eyepiece. Then look at the candidate "stars" and move in on the one which appears slightly fuzzy. Next use a higher power; if it's the globular, it will appear distinctly nonstellar at magnifications of 100x to 200x.

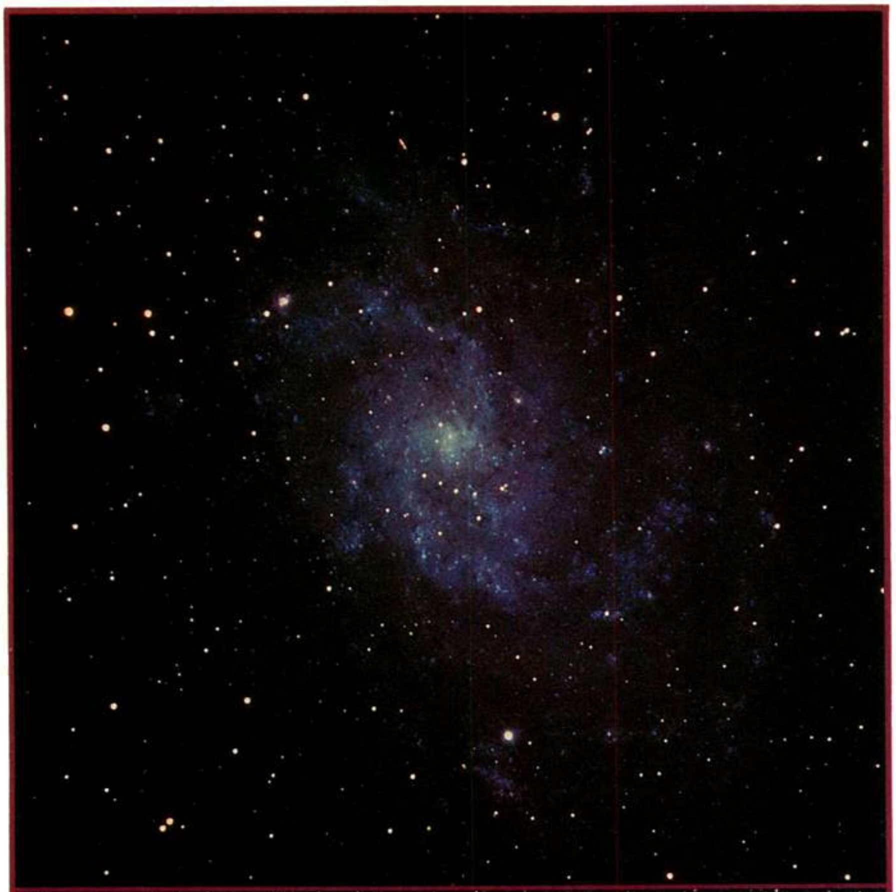
IC 1613, WLM, and the Pegasus Dwarf

Two more Local Group members lie in neighboring Cetus. The first is IC 1613 — an irregular galaxy lying at roughly the same distance as the Andromeda group. Photographs of this galaxy are reminiscent of the Magellanic Clouds, although IC 1613's total magnitude is 9.4 and its surface brightness is way down at 14.6 magnitudes per square arc-minute. The galaxy is bar-shaped, measures some 12' long, and is embedded in a halo of faint stars which are resolved in observatory photos. The density of stars is low which makes observing IC 1613 challenging, at best. A 10-inch reflector at low power normally shows a faint, even circle of light. A 17.5-inch telescope reveals that the galaxy brightens smoothly along its major axis, but also shows definite mottling. The last Local Group member in Cetus is named WLM — after astronomers Max Wolf, Kurt Lundmark, and P.J. Melotte, all of whom studied the galaxy early this century. An irregular system located about 870 kiloparsecs away, WLM is exceedingly hard to see. It measures 10.2' x 4.2' across and has a surface brightness of about 14.9. A large-aperture scope on a dark night may faintly reveal WLM.

Pegasus contains another irregular galaxy equally as difficult. Dubbed the Pegasus dwarf galaxy, it lies 170 kiloparsecs out, in our Galaxy's corona, and is smaller and fainter than the Sculptor or Fornax systems. Its small size, 4.6' x 3.0', keeps its surface brightness at 14.7, so a 12-inch telescope — under dark skies — may reveal it as a small, nebulous patch of light. With WLM and the Pegasus dwarf, be content with simply locating them — if you can see a faint smudge, you're doing well! Keep in mind that you're looking at two of the faintest and least massive star systems known.

Our Galaxy's Satellites

If you live in the southern hemisphere, you can observe the Magellanic Clouds as they hang high in the south during the summer months of November through January. The Clouds are our Milky Way's



M-33, the famous "pinwheel" galaxy in Triangulum (top), is difficult to spot with a small telescope. It has a low surface brightness, but is the nearest face-on spiral galaxy and reveals details to large telescopes on dark nights. Leo Henzl photo. M-31, the Andromeda Galaxy (bottom), is so large that it requires a wide-field ocular to view all of its nebulous spiral arms. M-31's core is a bright, yellowish oval and the galaxy's actual nucleus appears stellar at high powers. Marco Milani photo.

satellite companions and are relatively ordinary, irregular systems, but because they lie at distances of only 53 kiloparsecs (the Large Cloud) and 60 kiloparsecs (the Small Cloud), they offer more observable detail than other galaxies in the sky.

The Large Magellanic Cloud (LMC) measures some 10° by 8° in extent and shines with the combined light of a zero-magnitude star, roughly equivalent to the light of Rigel. The LMC fills a large chunk of Dorado and partly spills over into Chamaeleon. As with the Small Cloud, Europeans first learned of it from Portuguese sailors during the 15th century; later, they were named in honor of Ferdinand Magellan. In relation to the dwarf irregular systems, the LMC is enormous: it measures some 6.5 kiloparsecs from end to end — rivaling some spirals in size. Although classed as irregular, the LMC shows a central "bar" and faint outer spiral structure on long exposure photos.

A telescope shows many features in the LMC. The brightest object inside the galaxy is the enormous emission region NGC-2070, known as the Tarantula Nebula because of its spider-like appendages. NGC-2070 is one of the largest known emission nebulae and measures 250 parsecs across. It is visible in small telescopes as a bright and detailed nebulosity surpassing the Orion Nebula in splendor, despite being 20 times farther away. A bright star cluster in its center ionizes the gas and causes it to shine. Inside this cluster is the object called R136a, which is either a group of massive stars or perhaps the single most luminous and massive star known in the universe. Also in the LMC are the brilliant star cluster NGC-1910 (surrounding the variable star S Doradus), the emission nebula NGC-1936 — a large ring-shaped nebula which may be an old supernova remnant — and the planetary nebulae NGC-1714, NGC-1722, and NGC-1743.

The Small Magellanic Cloud in Tucana is decidedly less flamboyant, but still has much to offer. It measures 2½° by 5° across and glows with the light of a magnitude 2.3 star — the equivalent of Castor. Last year, astronomers in Australia discovered yet another Magellanic Cloud which appears to be a detached piece of the SMC itself. It lies behind the Small Cloud, and therefore appears as part of the SMC. In the SMC proper, the bright star clusters NGC-346 and NGC-371 show up in small telescopes as containing many stars; NGC-371 also contains nebulosity. The chain of open clusters — NGC-456 through NGC-465 — shows up well in large backyard telescopes, and is one of the better examples of an extragalactic stellar association. Two globular clusters belonging to the SMC — NGC-121 and NGC-419 — shine at magnitudes 11 and 10 respectively; although small, they are easy to pick out from the background clutter.

The Local Group of Galaxies

Object	M#	Type	R.A. (2000)	Dec.	Mag	SB	Size	Diameter	Distance	Con
WLM		Ib(s)m	0h 01.9m	−15°28′	11.0	14.9	10.2′ x 4.2′	1.3 kpc	870 kpc	Cet
IC 10		Ibm	0h 20.5m	+59°17′	10.3	13.5	5.1′ x 4.3′	1.3 kpc	1260 kpc	Cas
NGC-147		E5pec	0h 33.3m	+48°30′	9.5	14.5	12.9′ x 8.1′	1.3 kpc	760 kpc	Cas
NGC-185		E3pec	0h 39.0m	+48°20′	9.2	14.3	11.5′ x 9.8′	0.7 kpc	760 kpc	Cas
NGC-205		E5pec	0h 40.3m	+41°41′	8.0	13.6	17.4′ x 9.8′	1.5 kpc	760 kpc	And
NGC-221	M-32	cE2	0h 42.7m	+40°52′	8.2	12.3	7.6′ x 5.8′	0.6 kpc	760 kpc	And
NGC-224	M-31	SA(s)b	0h 42.7m	+41°16′	3.5	13.4	177.8′ x 63.1′	55.2 kpc	760 kpc	And
SMC		Ib(s)mpec	0h 51.7m	−73°14′	2.3	13.8	282.0′ x 158.0′	2.9 kpc	60 kpc	Tuc
Sculptor		E3pec	1h 00.0m	−33°42′	9.0:	—	—	—	110 kpc	Scl
IC 1613		Iab(s)m	1h 05.1m	+02°08′	9.4	14.6	12.0′ x 11.2′	1.7 kpc	690 kpc	Cet
NGC-598	M-33	SA(s)cd	1h 33.9m	+30°39′	5.7	14.0	61.7′ x 38.9′	20 kpc	1100 kpc	Tri
Maffei 1			2h 36.3m	+59°39′	—	19.6	—	—	1000 kpc	Cas
Fornax		E0pec	2h 39.9m	−34°32′	9.9(B)	15.1(B)	20.0′ x 13.8′	—	230 kpc	For
LMC		SB(s)m	5h 19.7m	−68°57′	0.1	13.8	646.0′ x 550.0′	6.5 kpc	54 kpc	Dor
Carina			6h 41.6m	−50°58′	—	—	—	—	90 kpc	Car
Sextans B		Ib(s)m	9h 58.0m	+05°20′	11.4	14.2	4.6′ x 3.3′	—	—	Sex
Leo A		Ibm	9h 59.4m	+30°45′	12.6	15.4	4.9′ x 3.7′	—	1100 kpc	Leo
Sextans C		dE	10h 05.6m	+00°07′	—	—	—	—	140 kpc	Sex
Leo I		E3	10h 08.5m	+12°19′	10.1	15.0	10.7′ x 8.3′	—	230 kpc	Leo
Sextans A		Im	10h 11.1m	−04°43′	11.5	14.5	4.8′ x 4.1′	1.5 kpc	1000 kpc	Sex
Leo II		E0pec	11h 13.5m	+22°10′	11.5	17.1	14.5′ x 12.9′	—	230 kpc	Leo
UMa		dE	11h 29.2m	+28°59′	—	—	—	—	120 kpc	UMa
UMi		E4	15h 08.0m	+67°12′	—	—	32.4′ x 20.9′	—	80 kpc	UMi
Serpens		dE	15h 16.0m	−00°04′	—	—	—	—	—	Ser
Draco		E0pec	17h 20.0m	+57°55′	—	—	—	—	75 kpc	Dra
Milky Way		Sbc?	17h 45.7m	−29°00′	—	—	[galactic center]	—	10 kpc	Sgr
Pegasus		Im	23h 28.6m	+14°45′	12.0	14.7	4.6 x 3.0′	—	170 kpc	Peg

. . . and 11 more!

Returning to the northern hemisphere, we now turn our sights to the spring sky to examine the remaining dwarf galaxies. Three dwarf ellipticals lie in Leo. The first, Leo I, is relatively bright, but suffers from lying right next to the bright star Regulus. Leo I is a dwarf E3 galaxy 230 kiloparsecs distant, and has a total magnitude of 10.1 and dimensions of 10.7′ x 8.3′. Its surface brightness is still fairly high — at 15.0 — but its location makes it almost impossible to see. Astrophotographers, on the contrary, can record its ghostly presence in only 23 or 30 minutes exposure on 103a-films at f/5.

The other two galaxies in Leo are even fainter. Leo II lies at the same distance as Leo I, but has a total magnitude of 11.5 and dimensions of 14.5′ x 12.9′ — giving it a surface brightness of 17.1. Unfortunately, this is well beyond the realm of backyard deep-sky observing at the present time!

Leo A is an irregular galaxy approximately 1.1 megaparsecs away and measures 4.9′ x 3.2′ on the sky. It shines at magnitude 12.6 and because it is spread out, Leo A has a surface brightness of 15.4. This is feeble light — in fact, it may not be visible in amateur telescopes. However, it's worth a try on the blackest of nights.

Three additional Local Group members lie nearby in the constellation Sextans. Sextans A is an irregular galaxy some 1.0 megaparsecs distant; its magnitude of 11.5 is spread over 4.8′ x 4.1′ which results in a surface brightness of 14.5. This galaxy may be visible in telescopes 12 inches or more in aperture. Sextans B is almost identical, and Sextans C is a dwarf lying only 140 kiloparsecs away from us. It is very faint and may not be visible in backyard telescopes.

Five more galaxies round out the known members of our Local Group. They are dwarf elliptical systems in Carina, Draco, Serpens, Ursa Major, and Ursa Minor. These systems are probably beyond the reach of amateur observers. Undoubtedly, many more systems exist in the outer reaches of the Local Group but are relatively inconspicuous — even in professional telescopes.

Observing the Local Group of galaxies will give you experience in recognizing the wide range of forms, brightnesses, detail, and sizes of typical nearby galaxies. The degree of observing difficulty spans the spectrum: from the brightest galaxy in the sky — the Large Magellanic Cloud — to some of the faintest — such as Maffei 1 and the dwarf ellipticals; from the incredible detail in the Andromeda Galaxy and M-33, to the formless ambiguity of the Fornax and Sculptor systems. Practicing your observing techniques on these objects will sharpen your ability to perceive details in faint objects. It will also help you identify those few, friendly patches of fuzz which appear so far away, but on a cosmic scale live right next door.

— *David J. Eicher*

ASTRONOMY
Reviews

The New Astronomy
Nigel Henbest and Michael Marten
240 pages, hardcover, $24.95
Cambridge University Press (1983)

A large measure of astronomy's fascination lies in the diversity and beauty of sky objects. Nonetheless, because of our restricted visual sense, we experience only a small portion of all that is really out there.

Just over half the Sun's output of energy, for instance, is visible light. We can detect a little of its invisible radiation as heat, but we are quite unable to experience the balance of our star's radiation. If we could perceive our Sun, golden-ringed Saturn, the Andromeda galaxy, or remote stellar systems at frequencies other than those connected with vision, our perspective on such objects would be profoundly altered. Similarly, if we could receive and comprehend the boundless waves of radiation that wash over and around our planet, the universe would prove to be vastly more complex.

British science writers and researchers Nigel Henbest and Michael Marten have collaborated to produce *The New Astronomy*, a book remarkable for its color photographs and lucid, accurate comparisons of optical and non-optical astronomy.

What is this "new astronomy"? Simply, it is the detection of non-visible radiation of frequencies on either side of the visual band of the electromagnetic spectrum — radio, infrared, ultraviolet, X-ray, and gamma-ray radiation. Henbest and Marten blend text and photographs to explore and describe the realm of non-optical astronomy in a penetrating and highly readable way. Readers will discover a wealth of sharp, exactingly reproduced color plates, nearly one per page, and, in many cases, two or more. The volume features over 30 familiar sky objects ranging from planets, nebulae, and galaxies, to enigmatic objects such as SS 433 and a mysterious double quasar. For each object in the book, there is a standard white-light photograph plus accompanying comparison images obtained by instruments working in non-optical parts of the spectrum.

Books containing lots of bright color commonly have rather superficial texts, but such is not the case here. The authors describe clearly and knowledgeably, and in simple language, the fundamental operations of each type of non-optical detector. They explain how the information and data are obtained, and how we gain knowledge of the universe by means of them.

The authors have chosen a logical and structured format. Odd-numbered chapters describe the detector or telescope, while even-numbered chapters explain the data and photographs generated by each instrument. When they refer to a photograph on the same or facing page, the reference appears in boldface type. Thus browsers can effortlessly scan the book, take note of an interesting photo, and go directly to the text pertaining to the photograph. Furthermore, the book is neither dry nor "textbooky." The opening chapter is a crisply written account of the electromagnetic spectrum, types of radiation, their sources, identifying characteristics, and the means by which this radiation is detected. Armed with this information, virtually every interested reader will find the balance of the book easy to comprehend and enjoy.

One chapter is devoted to optical astronomy and is a photographic survey of various types of telescopes and world sites for large professional instruments. The authors describe false-color imaging, its processing, the fundamentals of spectroscopy, and types of emission in the visible spectrum.

In another chapter titled "Starbirth," the reader is transported on a photographic and verbal journey along the spiral arms of our Galaxy. Some impressive sights are encountered en route, as they might appear if our eyes could receive a wider range of frequencies.

The characteristically multi-hued, low definition "new astronomy" photographs in the book will be familiar to many readers. Henbest and Marten show clearly how the photos are interpreted and how they are important to researchers. As a result, the colorful pages are pleasing to look at and are filled with useful information.

Author Henbest strikes the keynote when he writes, "Traditional astronomy was an effort to understand the symphony of the Universe with ears which could hear only middle C and the two notes immediately adjacent." I suspect *The New Astronomy* will open up much more of the universe for many readers. *Gail O. Clark.*

The Radio Universe, third edition
J. S. Hey
246 pages, softcover, $13.50
Pergamon (1983)

The author provides a short historical introduction to radio astronomy and then explains how radio waves behave, the logistics of radio telescopes, radio emission in the solar system, radar astronomy, the importance of galactic 21-cm line emission, and radio galaxies and quasars.

Atlas of Deep-Sky Splendors, fourth edition
Hans Vehrenberg
242 pages, hardcover, $39.95
Cambridge University Press (1983)

For dedicated deep-sky observers, Hans Vehrenberg's *Atlas of Deep-Sky Splendors* has long been a classic. Originally published in the mid-1960s as *Mein Messier Buch* ("My Messier Book"), and updated three times since, this volume is a collection of 114 Schmidt camera plates taken by Vehrenberg and interspersed with bits of text and close-up photographs.

The main plates, produced by fast, wide-field Schmidts and enlarged only a little, have a reproduction scale of one arcminute per millimeter. Thus Vehrenberg achieves a nice big field of view that contains all of large objects like the Andromeda Galaxy and the Veil Nebula — subjects that would spill across several fields of a normal telescope/camera setup. Vehrenberg pushed the Schmidts to their limits by seeking dark skies — in Germany for northern objects and Namibia for southern ones — and exposing, on Ilford HP-5, for 20 to 60 minutes per plate. He thus created a state-of-the-art amateur atlas of large deep-sky objects (small ones are hopelessly lost due to the scale of the photos).

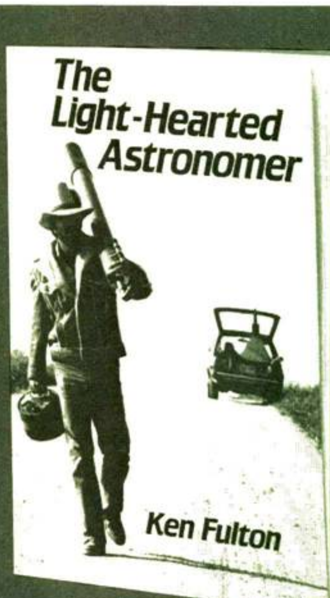
Perhaps the nicest feature of the book is that the plates are well printed, oriented correctly (with coordinate lines marked off on the margins), and appear at equivalent scales. Indeed it is rare to see a collection of deep-sky photos in which one can directly compare the relative sizes, brightness and structure of different objects. (Probably by intent, the scale roughly matches that of the Palomar Sky Survey; Vehrenberg's book is like having the Sky Survey plates of your favorite areas.) A couple of the photos are skewed and have differing scales — as is the case with the Magellanic Clouds and the Coma star cluster — and eight of the plates are reproduced in color, with differing scales. The plates all appear on *recto* pages, with text and occasional observatory photos on the facing *verso* leaves. The selection of some new observatory shots in this edition — primarily from Mauna Kea, Siding Spring, the U.S. Naval Observatory, and Cerro Tololo — is encouraging; but the decades-old and over-published Hale and Lick shots still dominate. Will they ever go away?

Vehrenberg's text is lucid and interesting, but it suffers from the all-too-common problem of being just a little too outdated. The state of knowledge on deep-sky objects is rather primitive and fast-changing — this will doubtless remain a problem haunting authors of deep-sky manuals for decades to come. Much of the crucial information about specific objects, such as magnitude, size, distance, age, diameter, surface brightness, and the like, simply does not exist or does not exist with any degree of certainty. Case in point: the best visual integrated magnitudes for planetary nebulae — the ones that appear in the best sources of deep-sky data and which are "carved in stone" — are no more than visual estimates made by astronomer Boris Vorontsov-Velyaminov during the 1930s. It's no wonder that major factual inconsistencies permeate discussions of deep-sky objects, and authors like Vehrenberg are stuck with deciding whom they should believe!

Fortunately, Vehrenberg is more perceptive than most; I certainly think of his atlas as being at the top end of reliability. His pictures exist as a unique experiment in contemporary amateur astronomy — one whose results belong on the bookshelf of every person who calls himself a deep-sky observer. *David J. Eicher.*

Weather and Climate Responses to Solar Variations
Billy M. McCormac, ed.
626 pages, hardcover, $29.50
Colorado Associated Universities Press
(1983)

This book contains most of the invited papers presented at the Second International Symposium, "Solar-Terrestrial Influences on Weather and Climate," held at Boulder, Colorado, in August 1982. The volume contains 53 papers and a review of solar variability, weather, and climate by J.A. Eddy. Topics include variations in the solar energy received at Earth, relations between solar activity and the upper atmosphere, and the apparent solar modulation of thunderstorms.



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Enhanced Images of Active Galaxies
Halton C. Arp
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Astronomical Society of the Pacific (1984)

Mount Wilson astronomer Halton Arp's controversial work on galaxies and quasars possibly related to them is the subject of this slide set, which consists of five color and 15 black-and-white negative slides. The galaxies included are all active, emitting large amounts of high-energy radiation, and/or may be physically associated with quasars of much higher redshift. Bright galaxies included are M-81, M-82, M-87, NGC-520, NGC-1097, NGC-4151, and Stephan's Quintet.

The Solar System
Roman Smoluchowski
174 pages, hardcover, no price given
Scientific American Books (1983)

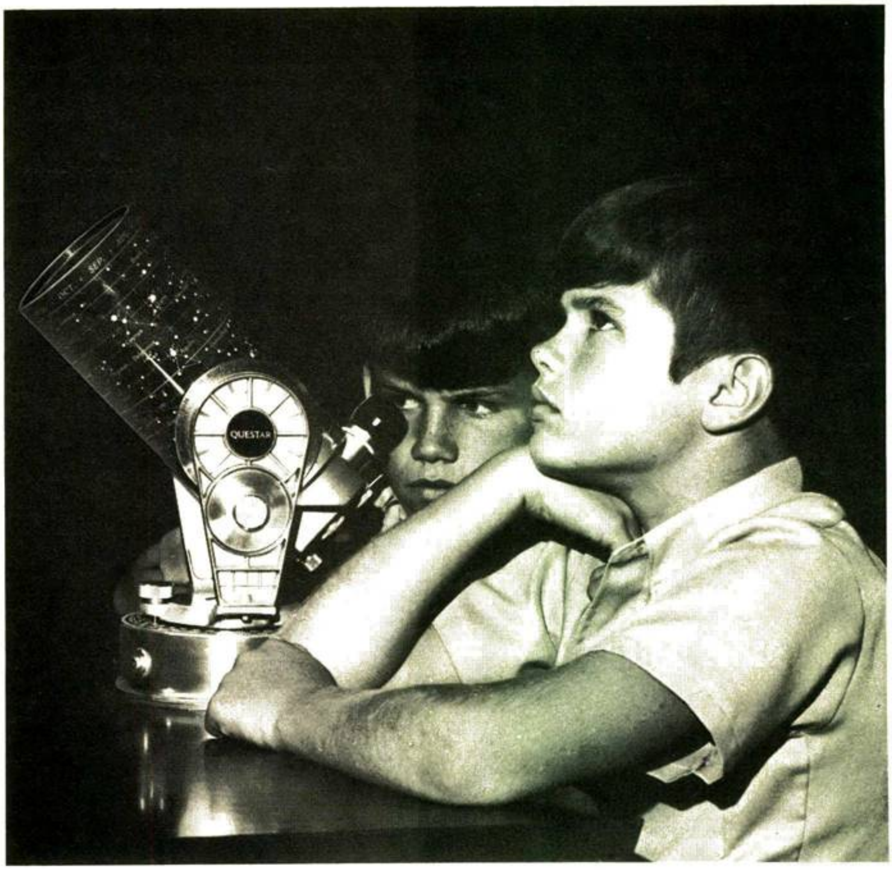
This book consists of a series of essays on various facets of the solar system and the bodies contained within it. The author examines the birth of the Sun and formation of the planets, and then details the characteristics of the hottest planets (Mercury and Venus), the water planets (Earth and Mars), the gaseous giants (Jupiter and Saturn), the cold planets (Uranus, Neptune, and Pluto) and the small bodies (asteroids, comets, and meteoroids). He concludes with a section dealing with life in the solar system.

Cosmic Horizons
Robert V. Wagoner and
Donald W. Goldsmith
195 pages, softcover, no price given
Freeman (1983)

A brief but informative textbook, *Cosmic Horizons* explores introductory cosmology, man's perception of the cosmos, the neighborhood (both in and outside our Galaxy), stellar evolution, large-scale cosmological structure and superclustering, and introductory particle physics. The book concludes with a short chapter on how astronomers interpret different types of radiation.

Glimpsing an Invisible Universe
Richard F. Hirsh
186 pages, hardcover, $39.50
Cambridge University Press (1983)

This book is subtitled "The Emergence of X-ray Astronomy," and covers the scientific, technological, and political hurdles that had to be overcome to carry on rocket and satellite X-ray observational astronomy. It is a technical narrative, primarily concerned with the astronomers and instruments that surveyed high-energy objects in the cosmos.



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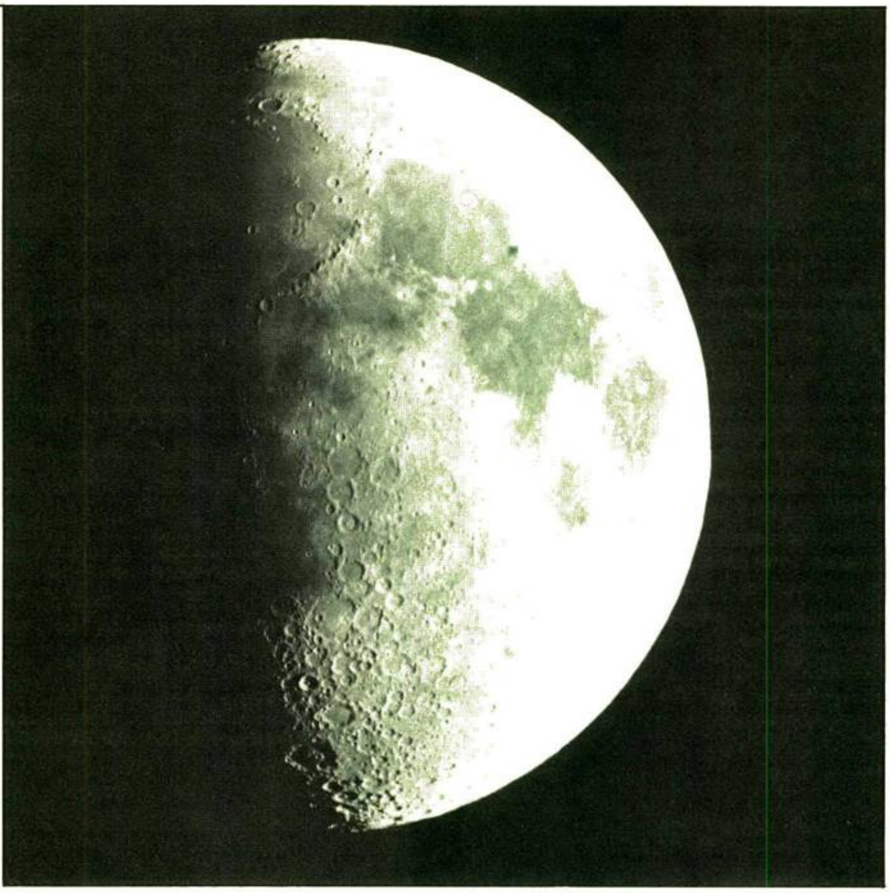
Venus Meets Jupiter

by Fred Schaaf



The Moon's broad maria and mottled surface are clearly visible to sharp-eyed observers without the aid of a telescope. This photo shows the terminator crossing Mare Nubium, and the distinct craters Tycho and Clavius near the Moon's southern limb. Lui Gonzalez photo.

This brilliant −6 magnitude fireball streaks across the sky over Finland, vaporizing after one second. The meteor could be a Perseid (although a bright sporadic is also a possibility). For more on meteor photography, see "Photographing Meteors in Winter" on page 75 of this issue. Pekka Parviainen photo.

The Wanderers

Back in January, the night sky's three brightest objects — the Moon, Venus, and Jupiter — converged in the dawn. This month the three will convene again, creating a splendid sight during the evening hours.

Venus lies along the southernmost part of the zodiac and is farthest south of the ecliptic on the 26th. Its increasing elongation from the Sun, which reaches 40° by month's end, gives it a sunset altitude of about 20° for viewers around 40° north latitude. Fortunately, 20° is high enough to permit distinct views of the conjunctions Venus will experience this month.

A spectacular Moon-Venus-Jupiter trio, when all three objects lie within a 5° circle, is rivaled only by a Venus-Lambda (λ) Sagittarii pairing on the 18th. At that time, the center of the 15-arc-second-wide planet, which shines at magnitude −4, lies just 10 arc-seconds north of magnitude 2.9 Lambda. American observers with telescopes should enjoy a nice view, although viewers in Alaska and British Columbia will witness an occultation (see The Backyard Astronomer for more details).

You don't need a telescope to enjoy watching the conjunction. In the United States, look for the group on the evening of the 18th and note how Venus seemingly replaces Lambda in its position in the Teapot of Sagittarius — you can imagine that the star has gone supernova for a night! You might also recall that just a month earlier, Mars lay 5 arc-minutes from this star and Jupiter was some 2° north.

The Venus-Jupiter encounter couldn't be better timed. It occurs on the weekend following Thanksgiving Day for United States observers when the two planets are close to the second-magnitude star Omega (*o*) Sagittarii, or Nunki, in the handle of the Teapot. Look for this star as far south of Venus on the 23rd as Venus is south of Jupiter on the 24th. That distance will be 2° 3′ at the moment of the Venus-Jupiter conjunction at 4:32 p.m. EST on the 24th. With Jupiter still around magnitude −2, the sight should be as impressive as when the planets were paired even more closely back in late January. Another similarity to the January conjunction is that, once again, the Moon comes gliding by to join the two brilliant planets.

The Moon's passage, just a day after the conjunction, is a stroke of good timing. In America on the 24th, you will see the two-day-old lunar crescent just a few degrees northeast of Mercury — a planet which reaches greatest eastern elongation of 22° the following day, but is low and inconspicuous even at the high point of this poor apparition. The high point occurs on the evening of the 26th, when most American observers will be able to see the Moon pass about 2° south of Venus and about 4° due south of Jupiter (close to Nunki) all within a two-hour period.

On the 6th, Venus is 6 arc-minutes north of 3.4 magnitude Theta (*θ*) Ophiuchi and on the 13th, is 3° 6′ south of dim Neptune. Another Venus conjunction occurs at on the 15th when binoculars will show Venus a mere 34 arc-seconds north of the 6.3 magnitude star SAO 186350.

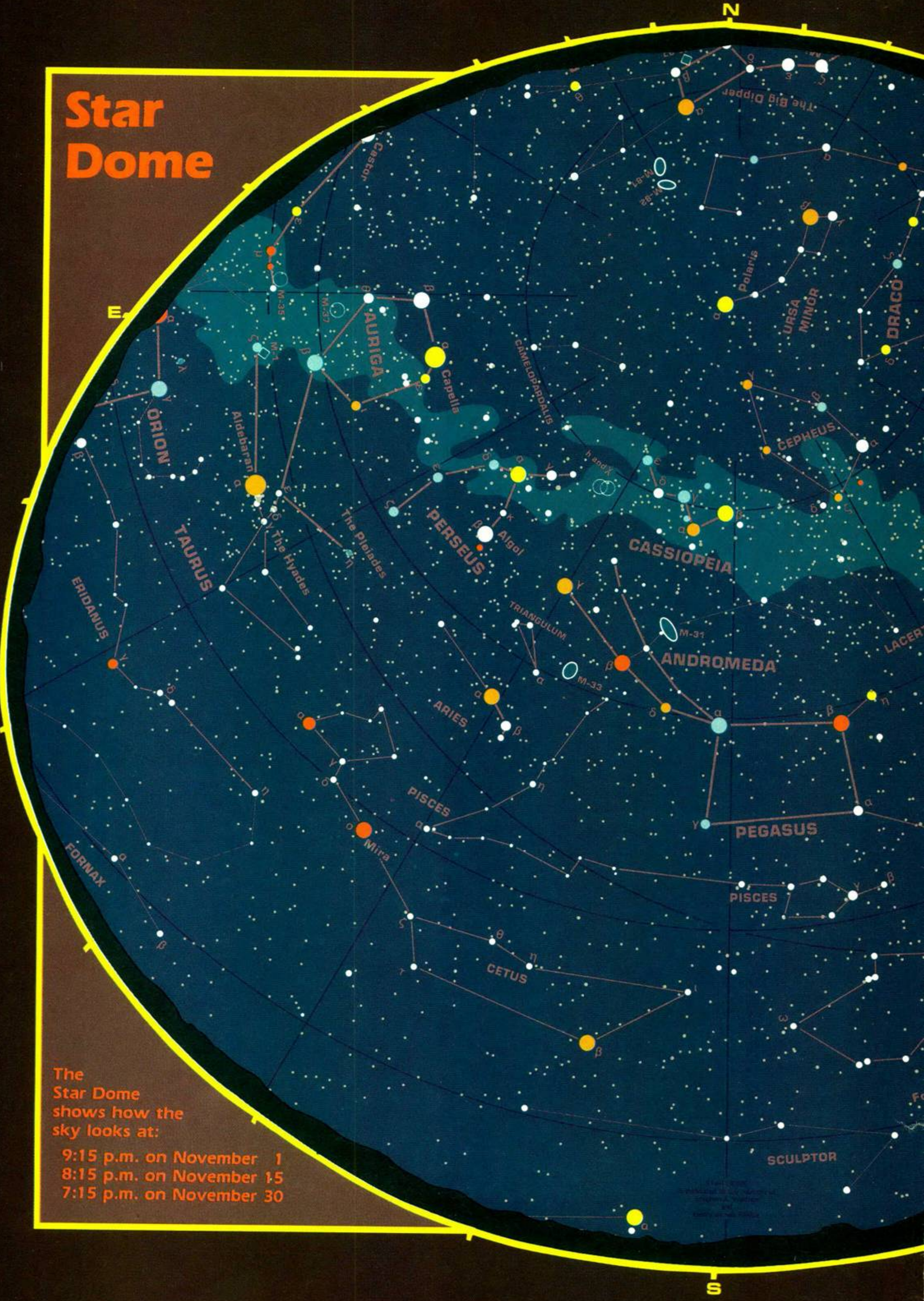
A total eclipse of the **Sun** occurs on November 22 — Thanksgiving Day in the U.S. — but the grand phenomenon takes place half a world away in New Guinea and the western South Pacific.

Mercury lies three arc-minutes north of Delta (*δ*) Scorpii on the 8th, 2° 19′ north of Antares on the 12th, and 2° 27′ south of Uranus on the 15th — but all these events are well immersed in twilight and consequently hard to see.

The planet **Mars**, on the other hand, is easy to observe this month. Although it fades to dimmer than magnitude 0.5 during the month, the Red Planet continues to "race" eastward and loses only about 7° of elongation from the Sun

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Star Dome


N
E
S
The Big Dipper
M-81
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Castor
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DRACO
CAMELOPARDALIS
ORION
Aldebaran
CEPHEUS
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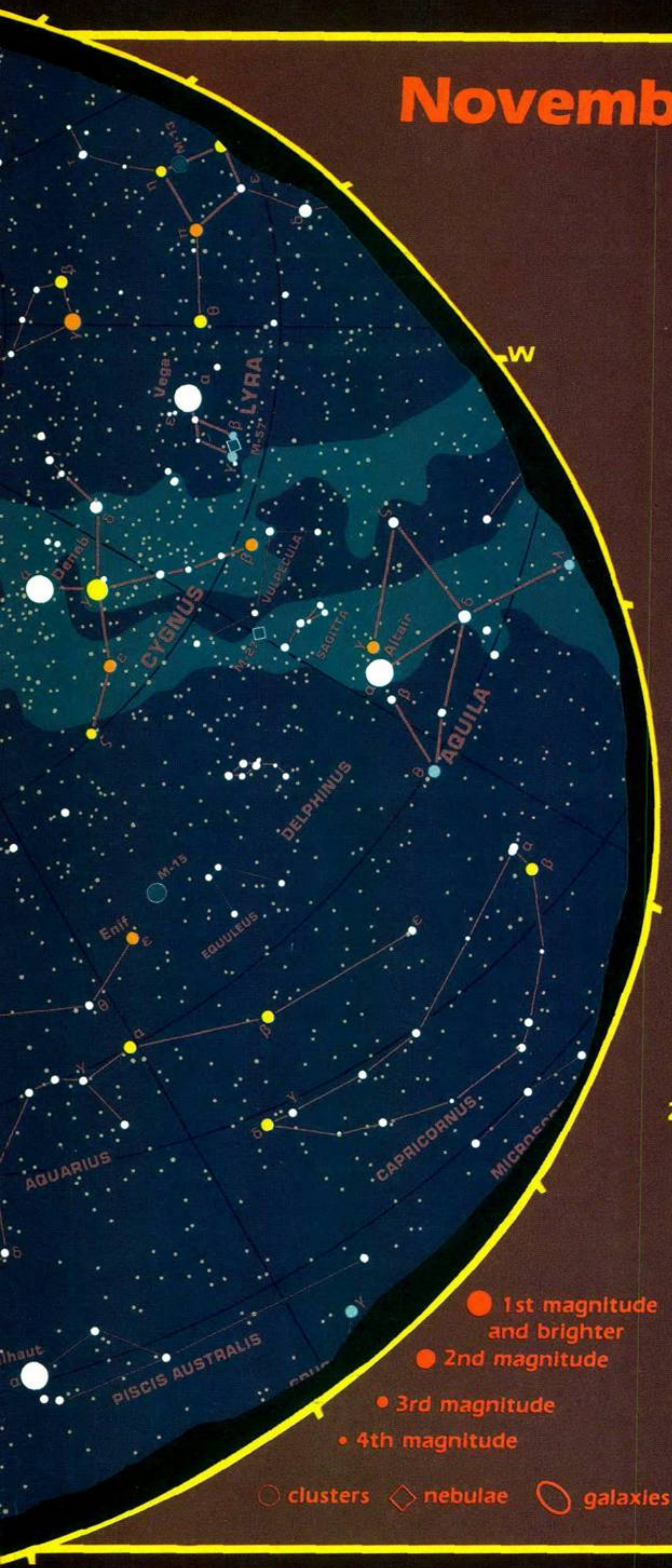
PERSEUS
Algol
TAURUS
The Hyades
The Pleiades
CASSIOPEIA
ERIDANUS
TRIANGULUM
M-31
ANDROMEDA
M-33
LACERTA
ARIES
PISCES
Mira
PEGASUS
FORNAX
PISCES
CETUS
SCULPTOR

The Star Dome shows how the sky looks at:

9:15 p.m. on November 1
8:15 p.m. on November 15
7:15 p.m. on November 30


W
M-13
Vega
LYRA
M-57
Deneb
CYGNUS
VULPECULA
SAGITTA
M-27
Altair
AQUILA
DELPHINUS
M-15
Enif
EQUULEUS
AQUARIUS
CAPRICORNUS
MICROSC
PISCIS AUSTRALIS
lhaut
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

November Sky Almanac

3rd The Taurid meteor shower peaks, best seen in the predawn hours.

4th The Moon is farthest from Earth at 5:39 p.m. EST: 252,085 miles.

8th Full Moon occurs at 12:43 p.m. EST.

11th Saturn is in conjunction with the Sun; it switches from the evening to morning sky, and will become visible low in the east shortly before sunrise by the end of this month.

15th Mid-November is the best time of year to observe summer and winter together. As soon as it gets dark, the last stars of summer are about to sink below the western horizon, while rising in the east are the glittering star-groups of winter; the Milky Way spans the sky from east to west.

16th Last Quarter Moon occurs at 1:59 a.m. EST.

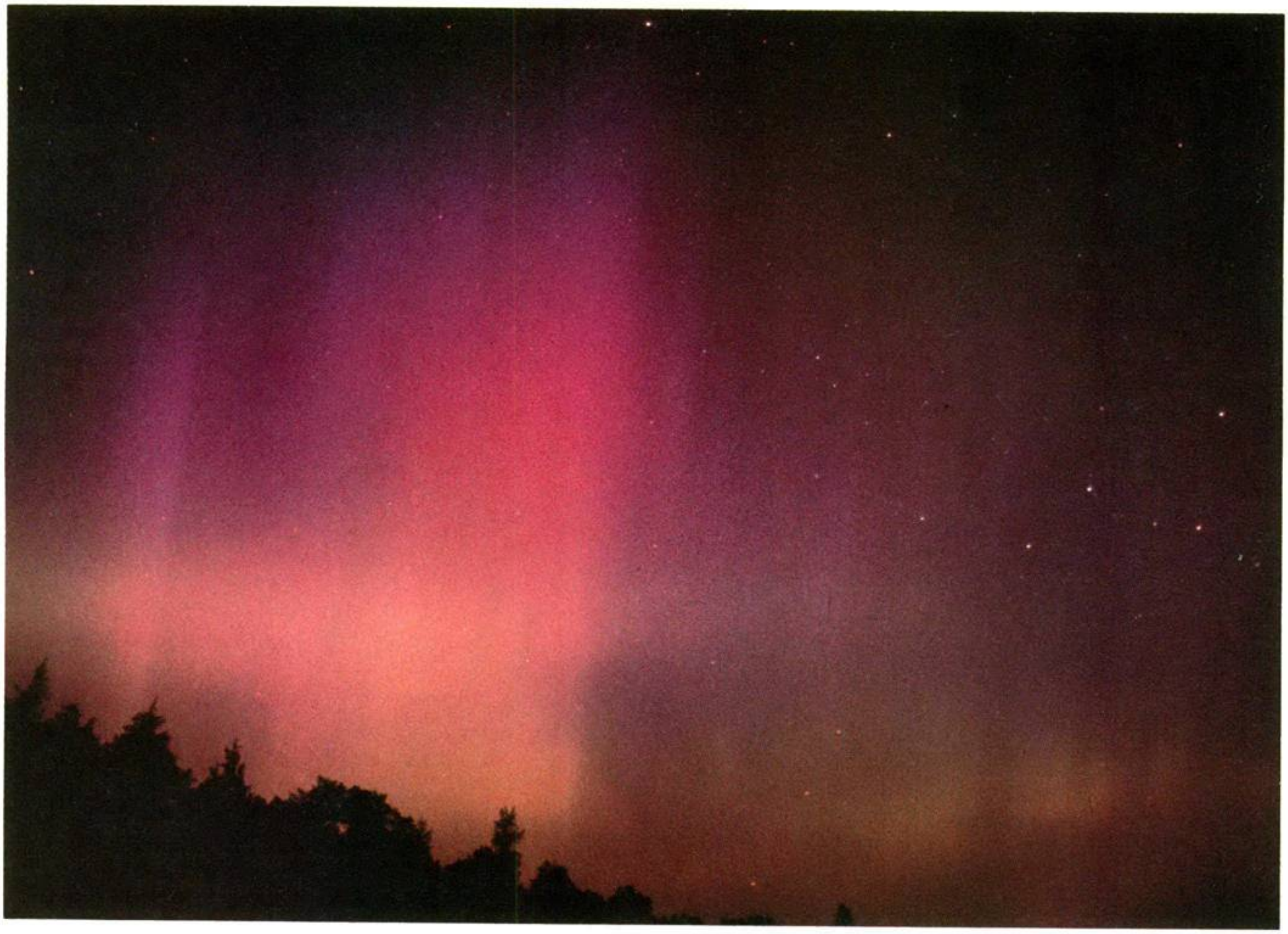
17th The Leonid meteor shower reaches peak activity in the predawn hours.

20th The Moon is closest to Earth at 3:52 p.m. EST: 225,449 miles.

22nd New Moon occurs at 5:57 p.m. EST; a total solar eclipse is visible in the western South Pacific.

25th Mercury is at greatest eastern elongation in the evening sky, but this is one of the year's poorest apparitions because the planet doesn't gain much elevation or visibility.

30th First Quarter Moon is at 3:00 a.m. EST.



during November. Its elongation of about 64° as the month ends is much greater than that of any other planet. Venus is in pursuit of Mars, but will not catch it until February; at month's end, Mars is still far to the northeast of Venus in the southwest evening sky. Jupiter then sets about 2½ hours after the Sun, Venus about 3, and Mars more than 4½.

During November, watch Mars scurry from Sagittarius up the ecliptic into the center of Capricornus. On the 13th, it is involved in an unusual conjunction: the planet lies four arc-minutes south of the center of the dim globular cluster M-75. Of course, viewing the cluster itself requires a telescope, as the ball of stars shines at only ninth magnitude.

On the other hand, observers with dark skies and binoculars can look for the 6.9 magnitude asteroid **Ceres** (at opposition on November 10) when it lies 5 arc-minutes south of Lambda (λ) Ceti (magnitude 4.7) on the 25th.

Saturn, one of the five classical planets, is not visible in November unless you glimpse it low in the dawn sky near month's end. This planet reaches superior conjunction on November 11, when it is also farthest from Earth (10.8 A.U.). In late November Saturn is a 0.7 magnitude object with a 15° separation from the Sun. Only one other planet, Pluto, is in the morning sky, and that is invisible in less than about a 10-inch telescope.

The Starry Sky

The name **Andromeda** first belonged to a heroine in Greek mythology, and was later attached to a constellation of stars representing her — Andromeda the Chained Maiden. In modern times, the name immediately brings to mind the brightest and closest spiral galaxy beyond our own — **M-31**, the Andromeda Galaxy, which is well-placed for viewing on November evenings.

A billion or so people live rather close to Earth's 40° north latitude circle; from this vantage point, M-31 passes almost directly through the zenith. Indeed, it is strange to think of the awesome mass and light of several hundred billion suns — lying more than 2.2 million light-years away — concentrated into a tiny fuzzy spot. Even across that vast distance, M-31 shines as a 3.5 magnitude object and the best photographs reveal that it stretches more then 5° along its long axis. In dark skies, naked-eye observers can glimpse over 2° of nebulosity.

The constellation Andromeda is primarily composed of a line of three bright stars: gold **Almach**, ruddy **Mirach** and blue-white **Alpheratz**. The last of these is Alpha (α) Andromedae, and although it is part of Andromeda, it is usually included in the giant asterism called the Great Square of Pegasus. Alpheratz and **Algenib** compose the east side of the so-called Square, **Scheat** and **Markab** the west side.

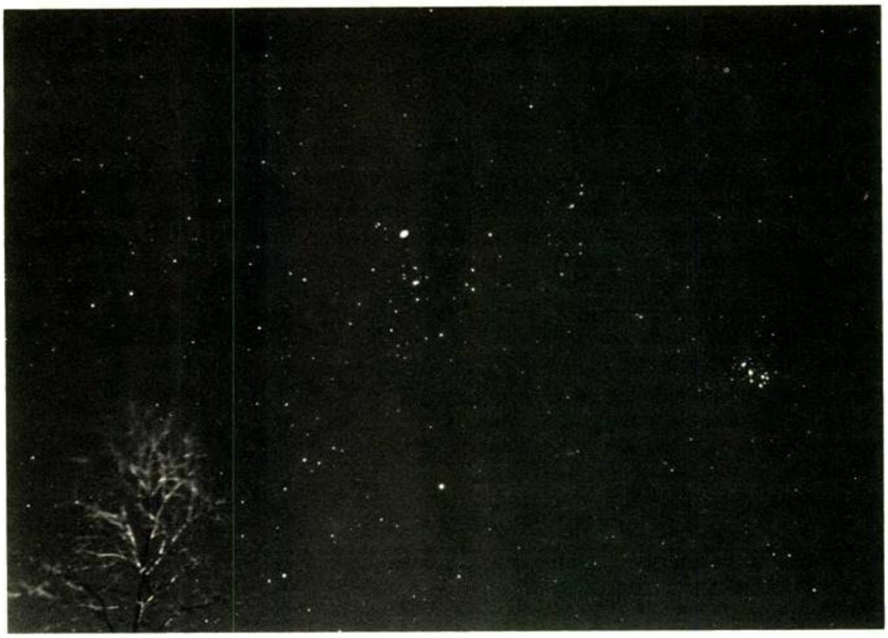
A line run through Alpheratz, Mirach, and Almach takes us on to **Mirfak**, a second-magnitude star marking the heart of **Perseus**. The rich collection of stars around Mirfak represents an association of young stars born together in a group. Do you see another star in gallant Perseus which is almost the equal of Mirfak? You probably do, but if not, then you are fortunate enough to be catching Perseus with its eerie variable star **Algol** in eclipse.

Algol is the brightest of all eclipsing binaries. At maximum brightness, its magnitude of 2.15 is similar to Almach, with which Algol and Mirfak form a right triangle. Every 2.9 days, a large partial eclipse of the brighter sun in the Algol system causes the star to fade to 3.4 over a five-hour span.

South of Almach and Mirach are two interesting smaller constellations: **Triangulum** the Triangle and **Aries** the Ram. The former is known for housing **M-33** — a large nearby galaxy — but both are compact and attractive. Aries is more compact and features the bright star **Hamal**.

There is no mistaking the **Pleiades** — a pocketful of naked-eye stars as bright as

With ISO 400 color film, a tripod, a fast lens, and a 30-second exposure, it's possible to record aurorae! Visible in this photo are Cassiopeia (right) and the North Star, Polaris (top center). Note how the hues change from gold, to bluish, to violet as the aurora stretches up to Polaris. Paul Walker photo.



November is the month for welcoming back Winter's familiar constellations, like Taurus the Bull. Composed primarily of two star clusters, the Hyades (left) and the Pleiades (right), Taurus rises early during November's chilly evenings. How many stars can you count in the Pleiades? Most people see six. Philip H. Niles photo.

magnitude 1.4, yet little more than a degree wide. Rising shortly after the Pleiades is "The Follower" — **Aldebaran** — which forms a triangle with the sprawling **Hyades** cluster and Pleiades, suggesting the handsome face of **Taurus** the Bull. **Capella** in **Auriga** twinkles at near zero magnitude, now higher than **Vega**, which is sinking in the northwest. **Orion** the Hunter and **Gemini** the Twins half-recline at the eastern horizon.

Before we leave autumnal constellations, however, there is one final pattern to consider — **Cetus** the Whale. The shapely head of the Whale features another bright second-magnitude star, **Menkar**, and this month the binocular asteroid Ceres is moving just past **Lambda** (λ) **Ceti**. In the neck of Cetus is the brightest of all long-period variables — **Mira** ("The Wonderful"). Unfortunately, Mira will not be visible this month because it is near minimum brightenss in its wide-ranging, 11-month-long period.

Skylore

Last month we saw how the stars of Aquarius became a "water-bearer" in the ancient Mesopotamian Kingdoms. Surprisingly, a different climatic coincidence seems to have been responsible for thoughts about the constellation in ancient Egypt. Perhaps the Greeks adopted their figure from Mesopotamian culture, but some factors suggest a link between Aquarius and various Greek and Egyptian gods.

While the Mesopotamian rainy season occurred during January and February, the Egyptian rain came at a different time of year. R.H. Allen, in his book *Star Names*, reports that these stars were once called Monius, from the word *muau*, meaning "water" in Egyptian. He says the American astronomer Garrett Serviss claimed "the ancient Egyptians imagined the setting of Aquarius caused the rising of the Nile, as he sank his huge urn in the water to fill it." The annual flood of the Nile did at one time coincide with the heliacal rising of Sirius, which the Egyptians once used to mark their New Year. At that latitude, Aquarius set as bright Sirius rose.

The next question is: what god did the Egyptians identify with Aquarius? Gertrude and James Jobes state the Egyptians of one period identified Aquarius as a form of their god Khnemu. Khnemu was creator of their world and natural choice to be the deity to dip a pot or urn and start the life-sustaining Nile flood. But the Jobeses also claim Sirius was regarded as a form of Khnemu. Perhaps it would be safer to associate both Sirius and Aquarius with the flood and Khnemu. To complicate matters further, Khnemu has also been connected with the planet Mars!

Several figures of Greek mythology were depicted in Aquarius, among them Ganymede, Deucalion, and Cecrops. There is a fascinating Egyptian connection in the lore concerning the one other figure of Greek mythology often identified with Aquarius — Aristaeus.

Aristaeus seems to have originally been the chief god on the Greek isle of Cos. His name, meaning "very good" or "the best," was a title applied to Zeus in Arcadia. Pindar writes that Aristaeus, having been fed nectar and ambrosia, was transformed into both Zeus and Apollo.

Why was Aristaeus associated with Aquarius? He may have been the child of Apollo by the powerful maiden Cyrene, who gave birth to him on the North African coast where the Greeks eventually erected a city named for her. Aristaeus later traveled to Cos where Sirius, the Dog Star, was combining its heat with the Sun's to cause a terrible drought. Aristaeus learned the Dog Star's wrath was directed at the islanders for harboring alleged murderers. Aristaeus had the murderers executed and then prayed to the Dog Star for forgiveness. His actions and prayer seemed to work: rains came and ever after the Etesian winds have helped cool Greece during the hot summers.

So Aristaeus, like Aquarius, was a rain-bringer. No doubt you have already noted here, as in the Egyptian myth, the connection with the Dog Star. There is another link between the two which may be significant. Pliny wrote about the belief that honey is the spittle of certain stars and most especially that of Sirius, but Greek mythology says Aristaeus was the first to discover how to raise bees.

Could the story of Aristaeus (which originated in North Africa, formerly Egyptian territory, and thence spread to Greece) be derived from the Greek adoption of an Egyptian god? Sirius was once regarded as a form of the Egyptian god Thoth (see January 1982 Skylore) and Thoth was identified by the Greeks as their own god Hermes. It was Hermes who supposedly carried young Aristaeus to Mother Earth and the Horae to be fed divine food and transformed into full glory.

What, then, is our conclusion? Could it be that Thoth and Khnemu were brought to Greece and became, or were incorporated into, Hermes and Aristaeus, who continued to be represented by Sirius and Aquarius, respectively?

One final confusion is the blending of Thoth and Khnemu. The *Larousse Encyclopedia of Mythology* states that Thoth's worshipers at Hermopolis thought he, with his ibis-head, had hatched the world like a great bird. Khnemu is said to have moulded the world on his potter's wheel. But Thoth also created eight deities, so the original Egyptian name of Hermopolis was Khnum, which *Larousse* says means "City of the Eight." Yet in his discussion of the god Khnemu-Khnum, *Larousse* also states Khnum means "the Moulder." Possibly an Egyptologist could answer these questions brought on by the tangle of legends connected with the ancient constellation Aquarius.

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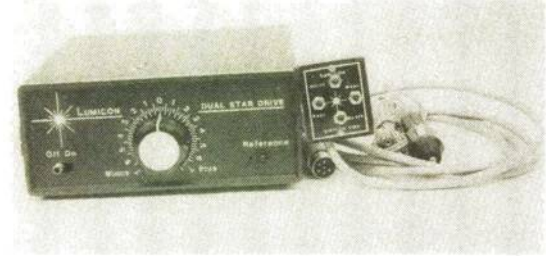

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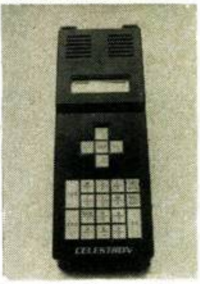

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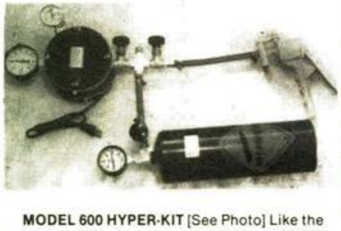

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Equipment Atlas

Television in Amateur Astronomy, Part 1

by
Peter Manly

Television has been part of the professional astronomer's repertoire for decades, but price and complexity have conspired to keep TV out of the hands of nearly all amateur astronomers. Recent advances, however, have produced very sensitive cameras small enough to fit on many amateur telescopes. Also, the cost of cameras, monitors, and video recorders has decreased to the point where they now cost no more than a commercially purchased 8-inch Schmidt-Cassegrain telescope. Clearly, the time is ripe for a detailed look at TV astronomy for backyard observers.

How Does a TV Camera Work?

In essence, the heart of a TV camera is an imaging tube, such as a Vidicon. The tube has a light-sensitive surface which is placed at the focal plane of the telescope. When the image strikes the sensitive surface (called the target), it causes an electrical charge to accumulate, the amount of which depends on the brightness of the light. The tube also contains an electron gun which makes repeated regular sweeps across the sensitized surface; wherever the beam meets an electrical charge, a small current will flow.

Suitably amplified, this current is the video signal. As the beam scans the target, the video signal varies according to the light input. After broadcast transmission, or traveling down a wire, this signal can be used to reconstruct the image on a TV monitor. With most TV cameras, scanning the target to read the video signal also destroys the electrical charge on the target; thus the image is erased at the same time it is read.

As soon as the beam passes a given point on the target, the incoming light begins to rebuild the electrical charge. This continues until the beam again sweeps past. Since it takes about 1/30 second to scan the whole target, a completely new picture is read out about 30 times a second. Therefore, each picture contains information from only the last 1/30 second.

This description applies to most, but not all, TV sensors. There are numerous tubes on the market with trade names such as Vidicons, Plumbicons, Saticons, Newvicons, and Ultricons. All work essentially the way described above and vary primarily in overall sensitivity. Two television sensors, however, work quite differently: the SIT (silicon intensified target) and the solid-state camera.

The SIT camera resembles a conventional Vidicon except that half of an image intensifier is attached to the front end. An image intensifier is a device that amplifies the light falling on it. At one end it contains a glass photocathode which emits electrons when struck by light. High voltage accelerates these electrons and slams them into a phosphor screen at the other end of the tube, creating a duplicate of the input image many times brighter than the original. In an SIT camera, the light-emitting phosphor is replaced with an electron-sensitive target which stores and reads out just like a Vidicon target. Placing this special front end on a Vidicon results in vastly increased sensitivity, but also vastly increased cost. SIT cameras such as the RCA TC1040/HRO system are considerably larger than Vidicon types and often weigh too much for telescopes under about 12 inches in aperture.

Solid-state cameras fall into two broad categories: the CID (charge injection device) and CCD (charge-coupled device) cameras. They differ in how the signal is read but the sensing mechanics are alike. Both devices have thousands of tiny photodiodes etched onto a single piece of silicon. Each photodiode contains a circuit for storing a signal to indicate how much light is striking that photodiode. Each diode forms one picture element, or pixel. The circuitry samples the thousands of photodiodes in sequence, but one at a time, to see how much light they are detecting. This produces a signal which closely resembles the video signal from a Vidicon.

One problem with some CCD sensors is that the light-sensitive area of each pixel does not reach far enough to meet that of the picture element beside it; between each pixel is an area where the device is insensitive. For ordinary scenes this makes little difference, but in astronomy it can matter a lot. Star images that fall into this "dead zone" vanish, and a star moving across the CCD chip will disappear and reappear as if being viewed through a picket fence. CID cameras such as General Electric's 4TN2200A1 have no dead zone between pixels, and some of the newer CCD sensors illuminate the CCD from the rear where the device is sensitive over its whole area.

Shown at the prime focus of an 8-inch SCT, the Panasonic PK3150 color camera has a Newvicon tube and gives excellent video of the Moon and planets. Note the extra counterweights on the end of the tube. Peter Manly photo.

Solid-state sensors are much newer than the Vidicon types and their performance is improving rapidly. At present, they are about as sensitive as the older Vidicon types but are slightly more expensive. The most expensive solid-state cameras resolve images about as well as a Vidicon, but their ability to discriminate between different shades of grey is usually greater. In the years ahead, they promise to become smaller, more lightweight, more rugged, and to consume less power than Vidicon-type cameras.

Unfortunately, the two CCD cameras available today were designed for home use and are not suitable for astronomy. RCA's CC030 and Hitachi's UKC3400 cameras are actually larger and heavier than the tube types they are designed to replace! These cameras also have auto-focus auto-iris lenses which are not

removable; it is impossible to mount them directly on a telescope without considerable effort. In addition, it appears they are not as sensitive as the Newvicon tube-type cameras.

Yet CID and CCD sensors bear watching. They have much greater potential for improvement than tube types, which are currently near their theoretical limits of performance. Amateur astronomers have built solid-state camera systems around such popular types as the GE 4TN2200A1 CID camera head (see the report in *Telescope Making* #17, Fall 1982 issue), and some cameras have just become available which are compatible with standard TV displays and video recorders.

What Optical System is Best?

The TV camera determines the resolution of the whole system and, at best, can resolve only 512 by 640 pixels. This is about two or three times worse than what a "fair" telescope will yield. Atmospheric seeing effects are also well below the resolution of the TV system, at least until the focal length reaches about 160 inches.

The sensitivity of a TV system depends not only on the camera, but also the performance of the monitor you observe with and the telescope you use. Regarding the monitor, studies show that a point source — such as a star — is barely visible to most people on a properly-adjusted monitor (contrast high, brightness low) when there is about as much video signal from the star as there is noise in the signal. (Engineers call this a signal-to-noise ratio of one.) In line with this, it is essential to prevent the effective f/number of the system from getting so low that the sky background becomes very bright. Just as with long-exposure astrophotography, you have to avoid saturating your sensor with "sky fog" if you want to pick up faint objects.

Let's look at this a little more closely. In any discussion of sensitivity, the question arises of how to determine the optimum. You are forced to trade off field-of-view and sensitivity to extended sources (nebulae) in order to maximize sensitivity to stars. Since TV operates by sensing how many photons strike each pixel, you want to be sure that the maximum number of photons hits each pixel. If all the photons from one star enter one pixel while none go into the adjacent pixel, then we have maximum contrast. For this reason, avoid long focal lengths which cause the star's seeing disk to appear larger than a single pixel. On the other hand, short focal lengths which give small stellar images often have short f/ratios, thereby brightening the sky background.

Obviously, a happy compromise must be found where the f/number is high enough that the background doesn't swamp the signal and the focal length is short enough to keep the star images from ballooning. The "generic" 8-inch f/10 Schmidt-Cassegrain telescope adequately satisfies these criteria. (A TV camera on an 8-inch SCT operating at f/5 or f/10 will show stars down to about visual magnitude 5. With an image intensifier, the lower limit drops to magnitude 12 or 13.) Brighter extended objects such as the Moon and planets out through Saturn can be viewed easily, although dimmer objects — the Messier catalogue, for example — are too faint to be seen without an image intensifier. Scopes of up to 20-inch aperture have been used, but their long focal length means an extremely small field of view on the TV system. This requires a very accurately aligned finder scope to get the desired object within the field of view.

Sensitivity forces another compromise. Given that sensitivity increases with the number of photons per pixel, it might seem logical to shorten the focal length when viewing extended sources such as planets and nebulae. This compresses the image into a smaller area on the focal plane and concentrates more photons into each pixel. While this does increase sensitivity, it defeats the purpose of viewing such objects, since you can't see much detail on Jupiter if the planet's disk is only four or five pixels across! Basically, it comes down to this: telecompressors and tele-extenders can make the image either bright or big, but they can't do both at the same time.

For more sensitive camera tubes such as the Newvicon or Ultricon, operating at f/10 or f/20 is good for viewing planets and the Moon since they are already bright. At f/10 Saturn is almost too faint, but in dark skies on an 8-inch telescope you get a pretty good image. Under these conditions, Saturn spans about a tenth of the total picture height — not quite enough to see Cassini's Division, but the rings stand out nicely. Using the same telescope at f/10 or f/20 on Jupiter yields some very good views: the planet appears about the same size as Saturn's rings, with its banding easily visible. The Moon is bright enough to view in our 8-inch at f/20 or higher, though at longer focal lengths atmospheric seeing often imposes a limit.

However, there are methods to increase sensitivity without resorting to image intensifiers or exotic systems. One way to double the sensitivity without seriously affecting other components, such as video monitors and recorders, is to use "beam blanking." It works very simply. If the camera were to wait longer than 1/30 second between scans, the electrical charge in the target would be greater and the pickup tube would become more sensitive to fainter objects. This is exactly like taking a longer exposure in astrophotography.

Some industrial-grade surveillance cameras such as RCA's TC 2055/U may be modified to read every other frame and to use a blank beam on the alternate frame. This gives each frame twice the exposure before it is read. The drawback here is that the picture has a perceptible flicker since it is changing only 15 times a second as opposed to the normal 30. Pursuing this idea further, you could blank two frames out of three, but unless you use an expensive frame storage and instant replay system to fill in the missing frames, this technique isn't practical. More importantly, not many people can stand to look at a 10-frame-a-second flicker! (In addition, the target in most tubes is not designed to hold a charge for much longer than 1/30 second.)

To see deep-sky objects, plain-jane cameras are barely sensitive enough. For serious nebula viewing, you'll need an image intensifier. Once again you must trade off image size for sensitivity. Typically, the 8-inch SCT will perform well with an image intensifier at f/5. For brighter deep-sky objects — the Andromeda Galaxy, the Orion Nebula, M-13 in Hercules — f/10 works well and yields better resolution and detail. In the Hercules globular, for example, some of its outer stars can be resolved. We'll say more about intensifiers later.

Coupling Camera and Scope

In the past few years, newer TV cameras have become small enough not to overbalance most medium-size backyard telescopes. While they are heavy compared to 35mm cameras or cold cameras, you can attach one to generic SCTs without extra counterweights. Mounting on a Newtonian is usually more difficult since the camera sits farther from the r.a. and dec axes, requiring correspondingly more counterweights. Some of the lighter Newtonians on German equatorials may not be able to handle the added weight.

The TV camera tube usually goes at the prime focus of the instrument. When you need a longer focal length, use a common photographic tele-extender since this uses less light than eyepiece projection. (The optical degrading effect of the tele-extender won't matter as the TV camera already has low resolution.)

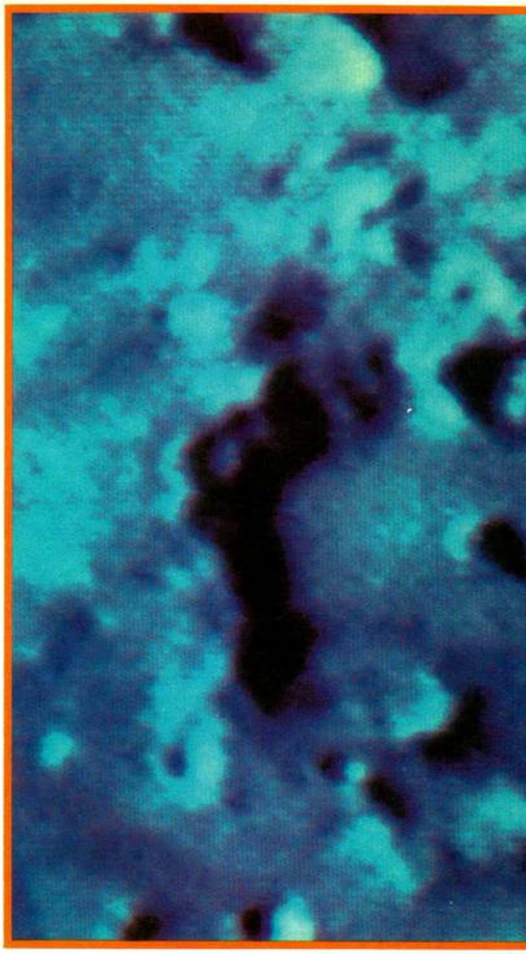
When you buy a TV camera, it's important to look for one with a removable lens. Most removable lens TV cameras have a C mount thread. This is smaller than most 35mm camera lens mounting threads, but adapters are available from telescope manufacturers and camera stores to convert from the standard T mount thread on a telescope to a C mount thread.

Most cameras are light enough to be supported by the eyepiece focuser, but with a yoke-mounted SCT, the camera sticks out too far to the rear to allow the telescope to swing through the fork. You can either put up with never seeing Polaris on TV, or you can use a star diagonal and a 1¼-inch-to-C adapter to bend the light path and let the camera sit off to one side. The latter arrangement usually means the camera must be supported externally, since few star diagonals will support the weight of the camera unaided. Most telescope manufacturers, however, make a piggyback mount for still cameras that bolts onto the back of the scope. With a little home-brew engineering, you could probably steady the TV camera with a bracket attached to the piggyback mount. (Of course, counterweighting now becomes trickier since the TV camera is hanging off the center of the optical axis.)

The light-sensitive area of most TV cameras is smaller than many photographic cameras, so the field of view is also smaller. For example, 35mm cameras have a frame diagonal of 43 millimeters, but the typical TV camera's diagonal is only 11mm and solid-state camera diagonals average about 6mm. Unless your finder scope is aligned exactly, you're going to have some problems locking onto a faint object.

If the TV camera has an image intensifier on its front end, its sensitivity may reach down to magnitude 9 or deeper. Very few finder scopes reach this faint, so other techniques come into play. One method is to locate some star bright enough to be seen in the finder and then to star-hop over to the object of interest using the monitor. This requires a set of star charts down to magnitude 9 (such as the *Smithsonian Astrophysical Observatory Star Atlas*).

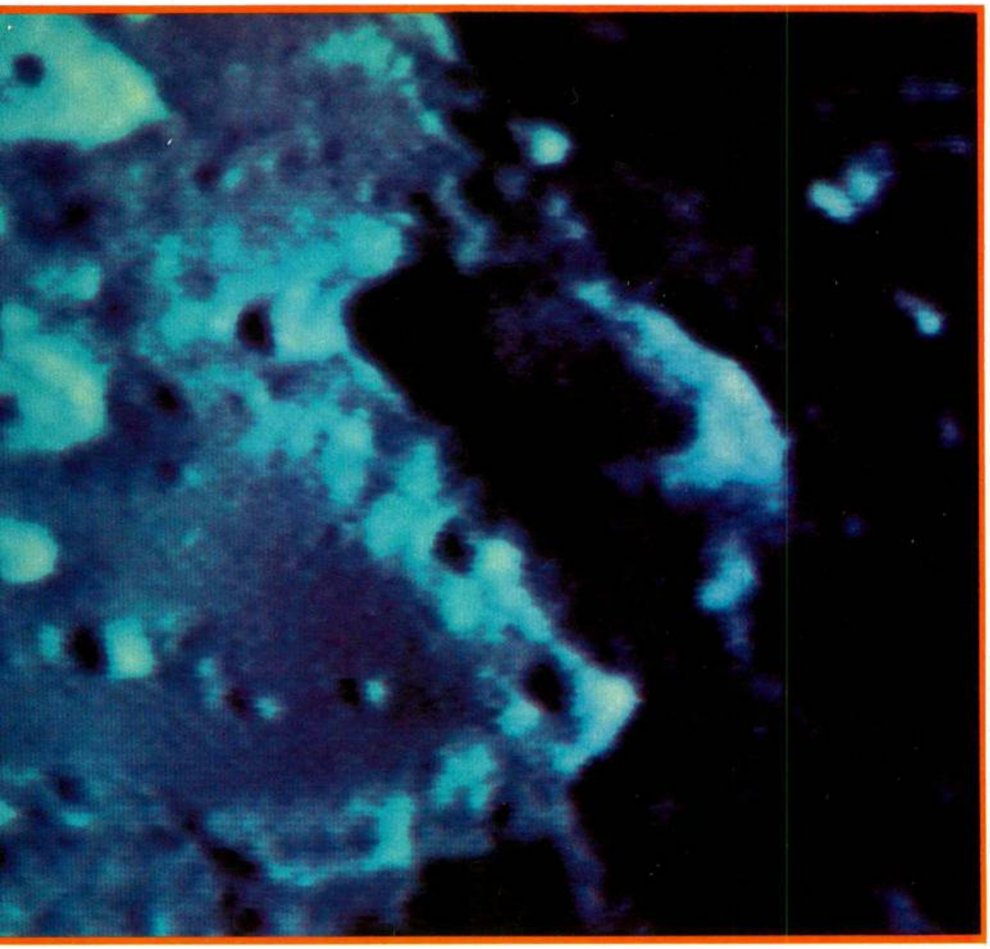
An alternative method is to attach a larger finder. I have a 90mm aperture Maksutov as a finder. To assure that the finder and main optics are exactly aligned, I installed a coupler that allows me to make very fine adjustments in pointing the Maksutov.



Viewing the Output

The commonest display is the video monitor, which can be connected directly to most TV cameras. For many people this will suffice, but some observers will naturally want to record what they see. The simplest method is photographing the monitor, although the photos usually show less detail and contrast than the monitor does. You'll have to experiment to learn what exposures and films give the best photos with a particular monitor. Direct photography of the monitor is relatively easy but static; for dynamic records you'll need a video tape recorder.

Recorders now come in both table and portable models. The two most popular formats, Beta and VHS, are incompatible, so you'll have to make a choice. Neither has a marked superiority over the other, but most amateur astronomers I have seen use the VHS format. Portable recorders will run on a 12-volt DC auto battery for field use, but are more expensive than table models. The major differences between recorders lie in the playback features such as stop-action freeze-frame, fast-forward search, and programmable tape counters. You will have to assess your need for these when you choose a recorder. If you are going to do anything that requires precise timing or stepping



The lunar crater Clavius and its environs show up clearly in this photo taken off a video monitor. The observation had been made with a 12-inch f/10 telescope and was replayed from tape. Photo by John Sanford.

through the record frame by frame (occultations, for instance), then a freeze-frame stop-action is useful.

Many cameras require a special power supply but some video recorders incorporate them. Most of the portable recorders have a special camera plug, so for field work you need only the recorder and camera. In addition, many portables have internal rechargeable batteries. For operation at home, these portables will operate from the recharger.

One feature I have found handy is a small monitor integrated with the video recorder. Most recorders do not have a monitor, so you'll need to carry a separate display plus batteries to power the monitor and cables to connect it to the camera and recorder. Some TV cameras have an electronic viewfinder, which is just a small built-in monitor, but these are generally poor and have no brightness or contrast controls. I have found them virtually useless for most astronomical scenes.

Image Intensifiers

While conventional home TV cameras can easily be used to view the Moon, the inner planets, the nearer gas giants, and some of the brighter stars, the real breakthrough in TV astronomy came with the addition of image intensifiers.

Image intensifiers amplify the intensity of light falling on their input surface while preserving spatial relationships and contrast of the image. As described previously, incoming photons strike photocathode material deposited on the inside surface of a faceplate. The cathode then emits low-velocity electrons which are accelerated by high voltage toward a phosphor similar to that on a TV screen. When these electrons strike the phosphor, they produce a brighter version of the incoming image. This output image is then piped into the TV camera. Most professional intensifiers use fiber optics to relay the light to the TV camera, but this is prohibitively expensive for backyard observers. A slightly less efficient but much less costly method uses a relay lens. There are a number of ways to accomplish this.

The first way works with intensifiers with built-in eyepieces which have been designed for visual use. The normal TV camera lens is focused to infinity and light from the intensifier's eyepiece is projected into the lens. A mechanical coupling keeps the eyepiece and the TV camera lens centered on each other. This is the least efficient method but requires few modifications to the equipment.

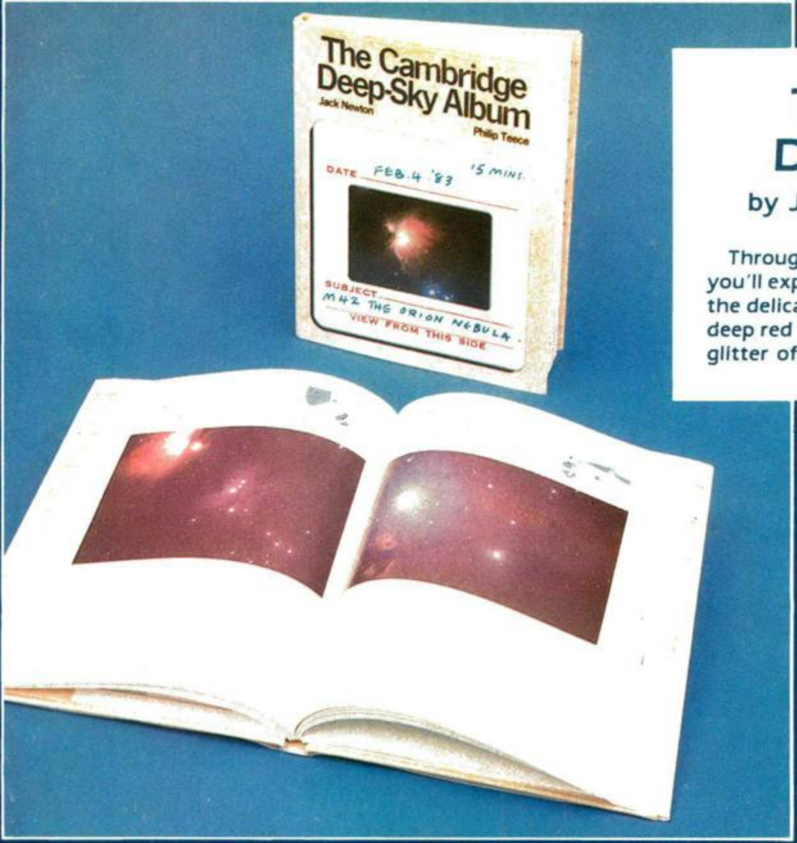
A second method eliminates the intensifier's eyepiece but requires a more sophisticated mechanical coupling between the intensifier and camera. Usually a TV camera's wide-angle lens can be used with a short C mount extension tube. This turns the wide-angle lens into a macro lens and allows the TV camera to focus on the intensifier's output phosphor screen, usually just a few centimeters from the front of the lens. You'll have to experiment somewhat to get the correct field of view and format size.

My intensifier has an 18mm diameter output phosphor; the TV camera has an 11mm diagonal rectangular input format. I used an old 16mm focal length TV camera lens on a 5mm C mount extension tube. Spacers hold the front of the lens to the back of the intensifier. The system works well and provides the slight reduction required to match the 18mm image intensifier output to the 11mm TV camera input.

Recently, Litton Industries began producing a relay lens to attach onto the image intensifier where the eyepiece normally goes. It re-images the light onto a focal plane a few centimeters behind the phosphor and has a standard C mount camera adapter thread. While the lens is not cheap, it is the most efficient I've found and requires no fussing or fiddling with parts or adapters. Everything is purchased off the shelf and ready to go.

Next month, we'll look at how these systems perform, and explore what you can do with them.

Peter Manly is an electronics engineer living in the Phoenix area. He has been an amateur astronomer since 1952, and rigged his first TV-telescope combination in 1972.



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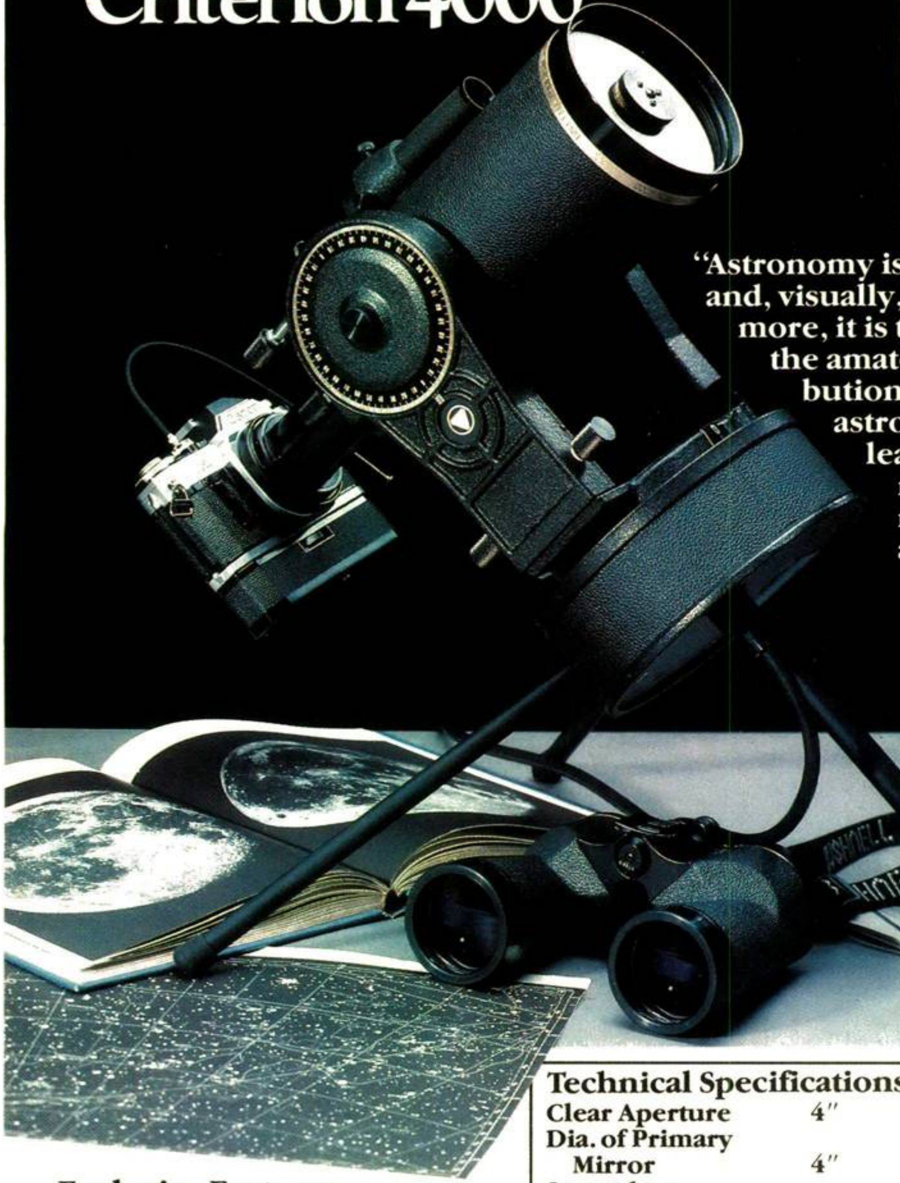

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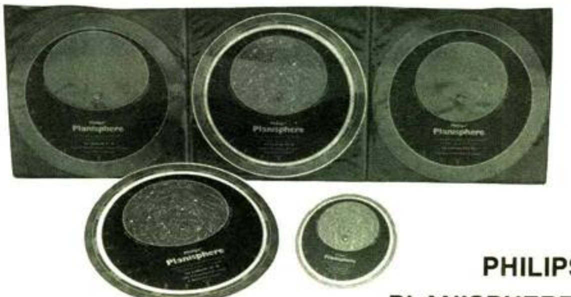

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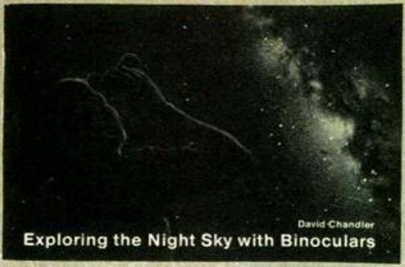
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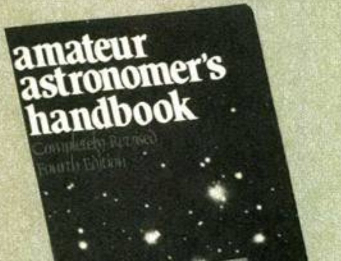
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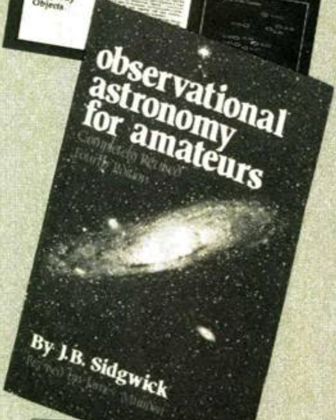
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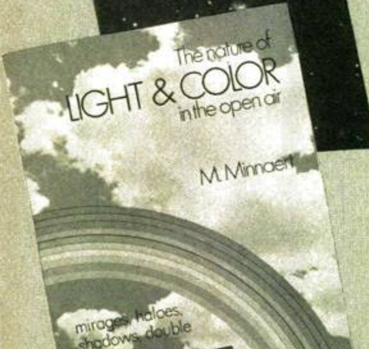
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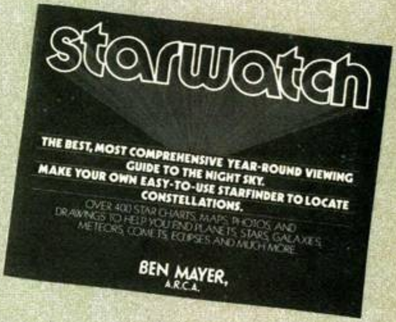
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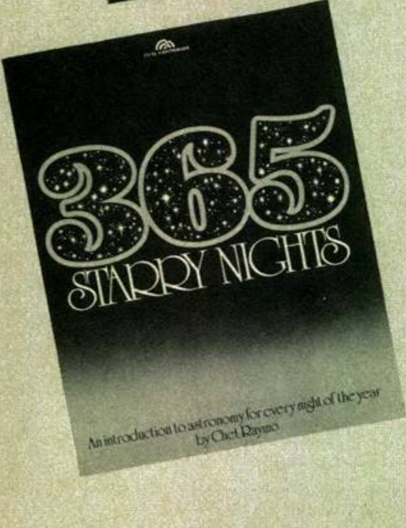
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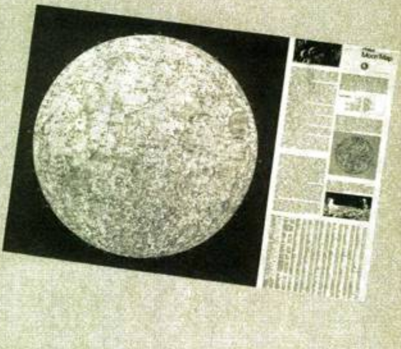

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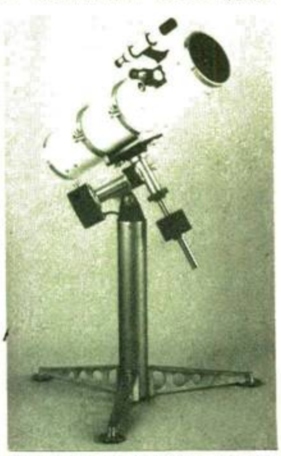

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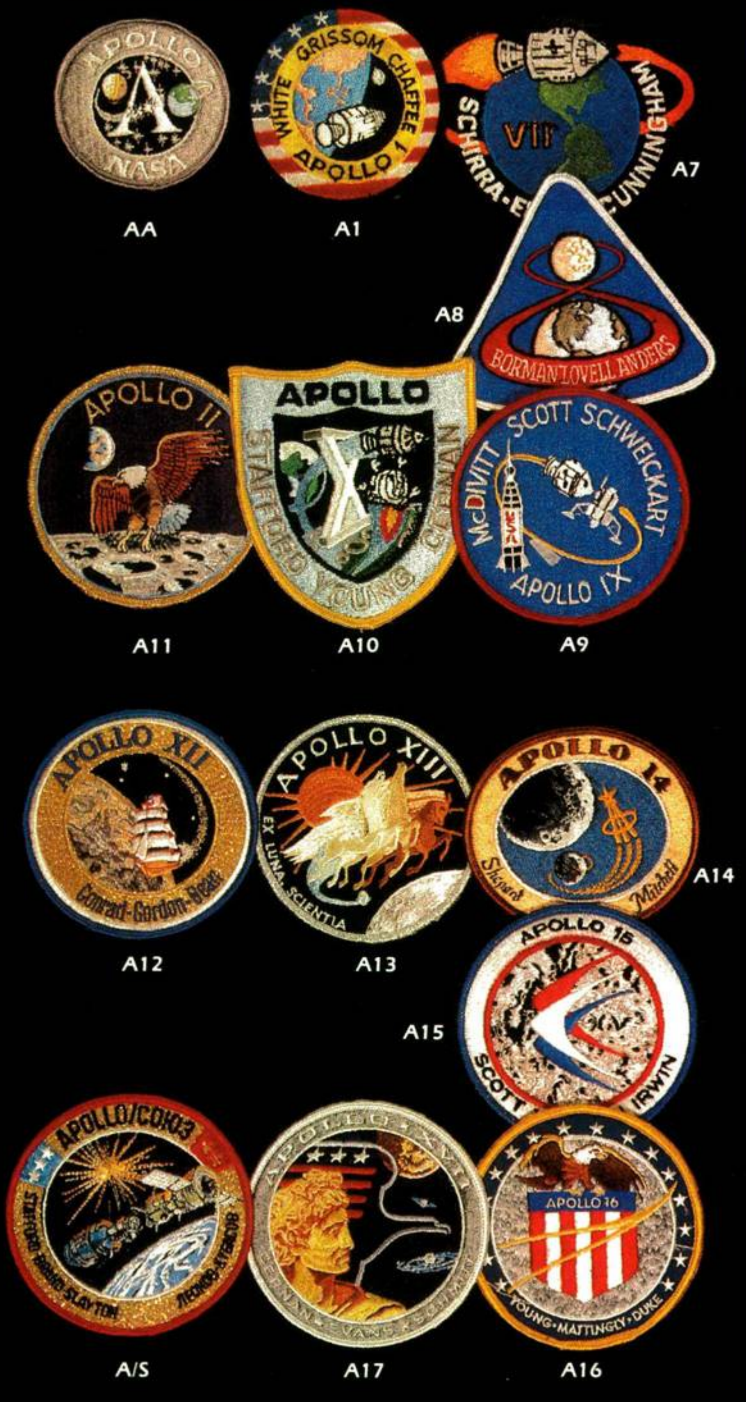
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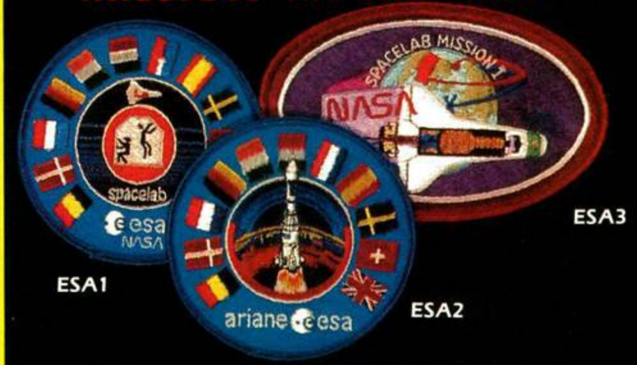
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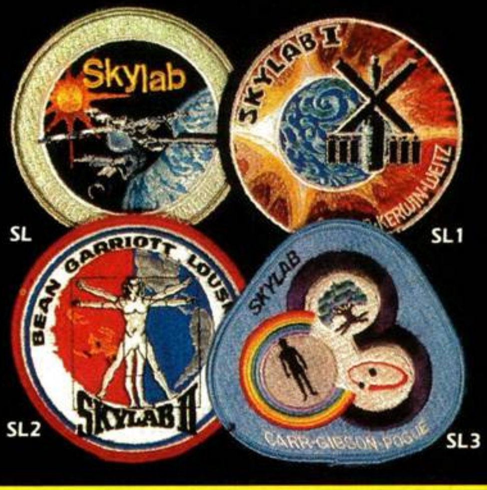
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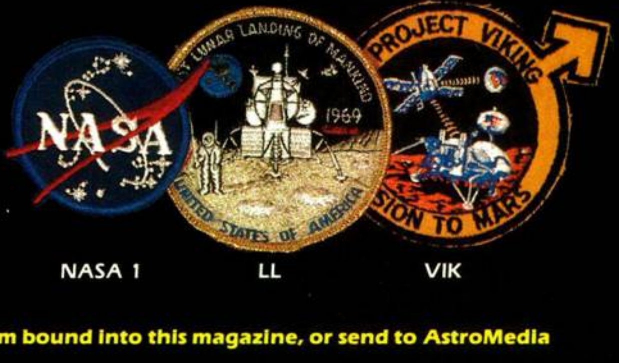
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ASTRONEWS

Saturn's Rings Thinner Than Believed

Results from an experiment designed by researchers at the University of California at Santa Cruz indicate that the vast rings of icy particles surrounding Saturn have a thickness of less than five meters, a fraction of the value of previous estimates.

Although recent estimates have relied on information returned by the Voyager spacecraft, the California research team obtained their figure for the rings' thickness from lab work alone. They designed and ran a unique experiment that allowed them to calculate the thickness of the extensive, halo-like ring system from direct experimental evidence. The researchers invented an inexpensive device, rigged with dime-store and machine-shop parts, to determine crucial information relating to the icy rings around Saturn. The resulting information fit into the fundamental equations for understanding Saturn's rings and produced answers that astronomers could only guess at until now. A report of the two-year-long study appears in the May 24 issue of *Nature*, a British science journal.

The study, initiated by associate professor Douglas Lin, combined theoretical astronomy, simple physical principles, and budget-minded inventiveness. Frank Bridges, professor of physics, and astronomy graduate student Artie Hatzes designed and built the experimental device to measure collisions between balls of ice, the stuff of Saturn's rings. Saturn's icy ring particles have collided countless times while orbiting the huge gas planet. Just how far apart the particles bounce after colliding — unknown prior to the Santa Cruz experiment — controls the structure and thickness of the rings.

Having measured the "bounce" of the ice balls, Lin calculated that the trillions of ice particles lie in a disk at most five meters thick. And since the largest ice particles are thought to be a few meters wide, the researchers say that their calculation implies that those large particles essentially form a monolayer — a sheet scarely thicker than its constituent particles — instead of the 50-to-100 meter thickness astronomers previously calculated.

The experimenter attached a ball of ice (molded by freezing a water-filled tennis ball) to the rim of a finely balanced wheel. By adjusting weights on the wheel, they altered its balance and caused it to rock in a slow pendulum-like oscillation. As the wheel rocked, the ice ball struck a stationary block of ice and rebounded. How far the ice ball rebounds after each collision provides the critical measure needed to determine the rings' thickness. To recreate Saturn's frigid temperatures, the ice-bouncing apparatus sits inside two styrofoam ice chests cooled with liquid nitrogen.

Pictures from the Voyager spacecraft flybys of Saturn reduced estimates of ring thickness from a few hundred kilometers to about 100 meters. Recent re-analysis of the Voyager data suggested that parts of the rings range from 10 to 50 meters thick. The finding of the California team represents what they consider to be the *maximum* possible thickness for the rings.

Although the researchers have succeeded in calculating the rings' thickness, they aren't yet ready to dismantle their rigging. They are now measuring how much ice fractures and chips off in a collision. Chipped-away snowflakes are later "recycled" by attaching to another ice ball, eventually settling into a steady pattern of erosion and reattachment. In addition, the researchers intend to use the device to study the more obscure rings surrounding Jupiter and Uranus.

On July 30, the Japanese observer Kesao Takamizawa discovered a 10th magnitude comet in northern Capricornus. During the first week of August, Comet Takamizawa (1984j) brightened to ninth magnitude and developed a 1°-long tail. Astronomers think it may be a short-period comet which passed perihelion during mid-July, meaning that it would fade as September neared. By August 1, it faded to 10th magnitude, causing its tail to weaken. Photo by Jack Marling.

New Results from IRAS

At the June meeting of the American Astronomical Society, held in Baltimore, Maryland, scientists reported that an unexpectedly high percentage of galaxies seen by the Infrared Astronomical Satellite (IRAS) are merging, colliding, or otherwise interacting with one another. This is but one of a number of interesting and unusual surprises gleaned from the mass of data left by the orbiting satellite, which ceased operations last November.

Last year IRAS observed about 20,000 galaxies, many of which emit more than half of their energy in far-infrared wavelengths. Recent studies indicate that as many as 25 percent of the most luminous of these infrared-bright galaxies may be part of interacting or merging groups of galaxies. As a comparison, less than five percent of all galaxies appear to be interacting when studied in visible light.

According to Carol J. Lonsdale of the Jet Propulsion Laboratory, the infrared energy from many of these interacting galaxies seems to be due to great bursts of star formation. Instead of producing one or two stars per year (as does the Milky Way), these infrared galaxies may have been shocked into releasing immense amounts of gravitational energy and producing up to a hundred times more stars per year than isolated spiral galaxies. An alternative explanation for the tremendous infrared emission detected from some of the galactic pairs could be that a source such as a black hole exists at the center of one or both of the merging galaxies.

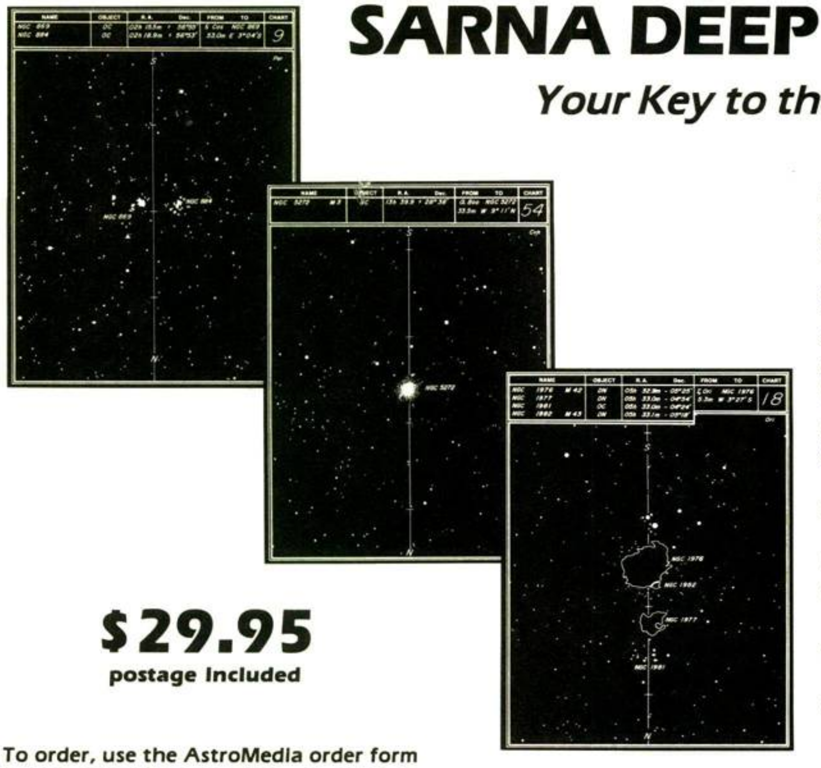
One example of a possible colliding galaxy studied in detail by IRAS is Arp 220 (see AstroNews, September 1984). Thomas Soifer of Caltech reported that analysis of IRAS data shows that the intense infrared emission from this galaxy probably results from a pair of galaxies that collided within the last 100 million years. Arp 220 is 100 times more luminous than normal spiral galaxies, with a power output equal to that of distant quasars — or about 2 trillion Suns. Almost all of its power output (99 percent) is emitted at far-infrared wavelengths. While the source of this energy remains unknown, it is most likely produced by a small core, perhaps a few thousand light-years across, within the colliding galaxy.

Characteristics displayed by Arp 220 are typical of some other objects discovered by IRAS last year and reported by James R. Houck of Cornell University, suggesting that some of the other unidentified objects may also be infrared galaxies. Such galaxies would be much more distant and might be even more luminous than Arp 220.

Lonsdale also reported IRAS studies of a peculiar object named Arp 243. Located about 300 million light-years from Earth, Arp 243 has been found to emit more than 95 percent of its total energy output at infrared wavelengths. Optical spectroscopy has already established the presence of many very young, luminous stars, so the infrared emission from these objects undoubtedly comes from great bursts of star formation triggered by the collision.

Other results from IRAS's discoveries included:

- In continuing studies of comets



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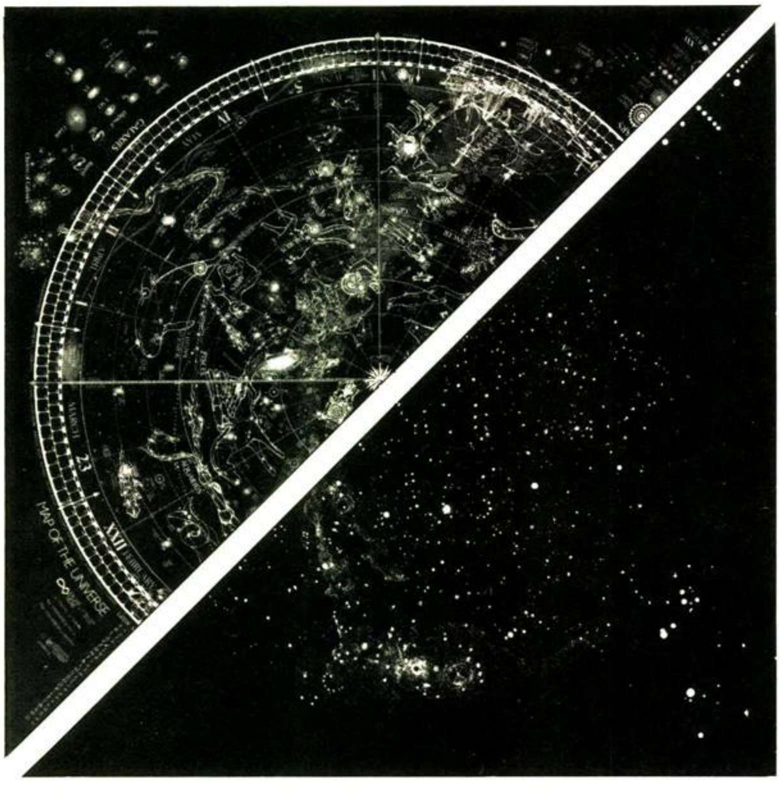

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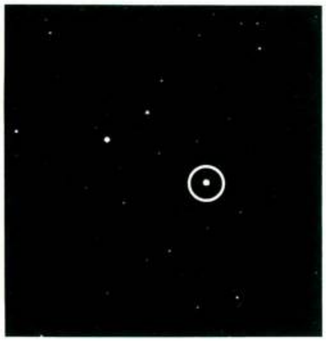
observed by the craft, astronomers found an extensive infrared tail of ice and dust on Comet Bowell stretching 22 million miles. The comet was observed while it lay beyond the orbit of Jupiter.

- Scientists have correlated IRAS observations of spiral galaxies in the Virgo, Coma Berenices, and Hercules galaxy clusters with radio and optical observations. The results of the study show that galaxies with more pronounced disks, younger stars, and large amounts of interstellar gas show brighter far-infrared luminosities than elliptical galaxies deficient in gas and dust.
- A very young star roughly the mass and brightness of the Sun has formed in the last 100,000 years in a nearby (450 light-years away) cloud of molecular hydrogen gas called Lynds 255.
- Statistical properties of the quarter-million infrared sources detected by IRAS as it mapped 98 percent of the sky show that most of the infrared objects emitting energy in the 12- and 25-μm region of the spectrum are old stars within our Galaxy. Looking away from the plane of the Milky Way, the sky as observed in the 60- to 100-μm region appears to be dominated not by nearby stars but by other galaxies.
- Analysis of data taken late in the IRAS mission has yielded new information about the zodiacal dust bands within our Solar System. These bands of warm (200° Kelvin) material orbit the Sun near the inner edge of the main asteroid belt, between the orbits of Mars and Jupiter. Debris from comets and collisions between asteroids are possible sources of this rocky material.
- IRAS observations of 47 Tucanae, a globular cluster containing a million stars, call into question our present understanding of these objects, which are thought to be the oldest in our Galaxy. The surprisingly small amount of far-infrared emission from 47 Tucanae suggests either that old stars return smaller amounts of dusty material to the interstellar medium than previously thought, or that the globular cluster has a very efficient means of sweeping out material — such as a high-velocity cluster wind. This globular cluster may have had its interstellar material swept away as it passed through the plane of the Galaxy.



On July 27, Minoru Wakuda discovered a nova in Vulpecula at α = 19h26m05s, δ = +27° 21′57″ (2000.0). Wakuda recorded the star at ninth magnitude; previous photos of the area showed nothing down to 12th magnitude. By August 1, the nova brightened to eighth magnitude, and Harvard-Smithsonian astronomer C.Y. Shao identified a 17th magnitude bluish double star on the Palomar Sky Survey which he thought was the pre-nova star. Photo by Jack Marling.

Voyager's Future

"The Voyager flight team, by virtue of having launched [the Voyager] hardware into interstellar space, incurs a responsiblity for documenting its eventual disposition, within the limits of current knowledge."

Thus Robert Cesarone, Senior Engineer of Voyager Navigation, Andrey Sergeyevsky, and Stuart Kerridge, members of the mission design section at the Jet Propulsion Laboratory, introduce a recent paper in the *Journal* of the British Interplanetary Society on the "Prospects for the Voyager Extra-Planetary and Interstellar Mission."

How long scientists will be able to receive significant data (defined as 20 bits per second) from the Voyager and Pioneer spacecraft depends on a number of things, the most critical of which are the ability of the Deep Space Network to send instructions to and receive data from the spacecraft, how long the propellant (required to point the spacecraft's main antenna toward Earth) will last, and the rate of decay of the spacecraft's nuclear power supplies. Assuming no catastrophic failures in these or other essential systems, calculating the survival chances for the spacecraft is fairly straightforward.

The Deep Space Network as it is now (18-kilowatt transmitters on 64-meter reflectors), can send commands to the Voyagers to a distance of 160 astronomical units. Voyager 1 will reach this distance in 2023 and Voyager 2 in 2029. Anticipated improvements (400-kilowatt transmitters on 70-meter reflectors) extend the range out to more than 800 AU.

Communications back to Earth, not surprisingly, prove far more constraining. The improved Deep Space Network should be able to receive 20 bits per second from Voyager 2 for more than 40 years after the Neptune encounter in 1989 — provided the spacecraft keeps its antenna pointed to within 30 arc-minutes of Earth. If Voyager 2 could keep pointing to within 10 arc-minutes, the distance over which data theoretically could be returned would about double — but at the price of far greater fuel consumption.

Cesarone calculates that Voyager 1 may begin 1990 with 30.3 kilograms of fuel remaining and Voyager 2, after two further planetary encounters (Uranus and Neptune), will have 22.4 kilograms. Given a reasonable balance between propellant usage and pointing, "both spacecraft have propellant and communications capability through the year 2030." Both spacecraft will thus run out of propellant long before they are unable to communicate.

The true limiting factor, however, turns out to be the radio-isotope thermoelectric generators — the nuclear power plants that provide the electricity to keep the craft "alive." These will slowly decay to the minimum useful level for Voyager 1 in 2012 and Voyager 2 in 2013, at distances of about 121 and 106 AU, respectively. Turning the four residual experiments off and on could probably extend this a further six years.

The Big Question, for which everyone involved awaits an answer, is whether any of the four spacecraft exiting the solar system at present (Pioneers 10 and 11, plus the two Voyagers) will, while still active, cross the heliopause — where the solar wind plows into the interstellar medium. Pioneer 10 is traveling along the heliosphere's tail, swept far behind the solar system by its motion through the Galaxy. Pioneer 10 has virtually no chance of reaching true interstellar space before it ceases to function.

However, if a model is correct that locates the heliopause at the mean distance of some 100 AU plus or minus 30 AU, then the expectations of reaching the heliopause with an operating spacecraft are 75% for Voyager 1 and 55% for Voyager 2. Pioneer 11, expected to survive through 1996 (i.e., 45 AU), stands only a very small chance of surviving to the heliopause.

Direct measurement of the interstellar medium is of possibly vital importance, among other reasons because conditions there may have a significant — perhaps even catastrophic — influence over Earth's climate. Therefore, a dedicated "interstellar precursor" mission that would overtake the Voyagers and carry on their measurements just as they are failing would be worthwhile. To be possible, launch would probably have to be around the turn of the century.

More immediately, it is possible that anomalies in the spacecrafts' velocities as they exit the solar system might reveal the presence of any large trans-neptunian body. If it were detected by more than one spacecraft, the body could probably be located as well. Cesarone concludes that "a spacecraft at 30 AU from the Sun . . . can sense a one solar mass [body] as far out as 700 AU and a 0.1 solar mass body about 350 AU. However, for a small Planet-X mass, such as 10^{-5} solar mass, the body would have to be at no more than 38 AU."

Modeling the trajectories through interstellar space of all four spacecraft, the Sun, and nearby stars permitted Cesarone and his co-workers to derive a chart showing nearby stellar flybys for each spacecraft that occur within three light-years of Earth:

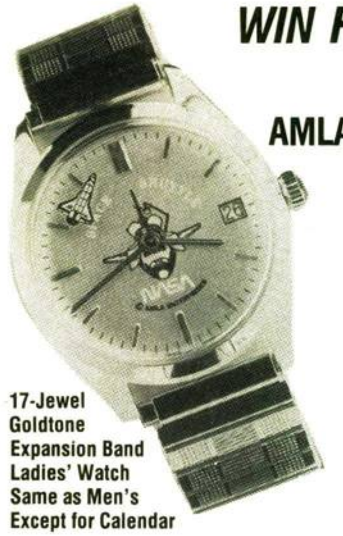
For Voyager 1, the closest pass is within 1.64 light-years of AC +79° 3888, an M-type dwarf, a little over 40,000 years from now and 2.97 light-years out from the solar system. (Remember, as time passes and stars move, Alpha Centauri will no longer be the nearest star to Earth.)

Pioneer 11, headed out of the system in roughly the same direction, may pass some 1.65 light-years from the same star in some 42,400 years and some 3.05 light-years out from Earth — also this spacecraft's closest encounter.

More interestingly, Voyager 2, given its current flight path through the Neptune system, could pass as close as 0.80 of a light-year from Sirius in 357,900 years, although at that time Sirius, at 19.94 light-years, will be more than twice as far from the solar system as it is at present. Other possible paths at the Neptune encounter could change this either a little closer to Sirius or, more likely, much farther away.

In either of the two most likely Neptune encounters, Voyager 2 would pass within some 2.8 light-years of now familiar AC +79° 3888 in approximately 47,000 years and around 3.8 light-years out.

Pioneer 10 may pass some 3.3 light-years from Ross 248 in 32,600 years and at a distance of 2.98 light-years. Oddly enough, Voyager 2,



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ASTRO NEWS

though exiting the solar system in a direction nearly opposite that of Pioneer 10, will also pass Ross 248 at 1.25 or 1.51 light-years in about 40,000 years, 3.19 or 3.23 light-years out — again, depending upon the path chosen for the Neptune encounter. This strange happenstance is possible because of Ross 248's high velocity toward the solar system. It will pass the Sun at some 2.9 light-years distance in roughly 34,900 years.

The model also shows that the solar system will pass some 20,000 AU from BD +61° 366 in about 814,900 years. However, all these measurements are subject to errors — even by as much as a light-year — due to the model's necessary simplification of actual interstellar motions and to probable errors in our knowledge of stellar velocities. Generally, the better a star has been studied, the more accurate the flyby data — thus the projection for Sirius is probably the most accurate.

Cesarone concludes by hoping these spacecraft will be remembered "not only as great adventures in planetary exploration, but also as mankind's first ventures into the realm of interstellar travel." *Donald Robertson.*

LHS 2924: Faintest Star

Many stars are famous because they're bright, but recently the red star LHS 2924 attracted much attention because it is *faint.* With an absolute visual magnitude of +20.0, LHS 2924 is the intrinsically faintest star known. Last year, Ronald Probst of Kitt Peak National Observatory and James Liebert of the University of Arizona's Steward Observatory found LHS 2924's spectrum and colors quite peculiar and proposed that the star could be a black dwarf — a star too small to burn its fuel. (See "Possible Black Dwarf Identified," AstroNews, January 1984.)

Now Liebert, Todd Boroson of Mt. Wilson and Las Campanas Observatories, and Mark Giampapa of the National Solar Observatory have taken a closer look at the strange star. Their observations, published recently in the *Astrophysical Journal,* confirm that LHS 2924 is a single, cool, low-mass star — very likely the coolest red dwarf yet known. The scientists say LHS 2924 is either a black dwarf or a very faint red dwarf burning hydrogen on the main sequence.

Although the star's very faint absolute magnitude and low temperature suggest that it's a black dwarf, the new data raise some doubts. Since black dwarfs do not burn hydrogen, they fade as they age, and become essentially undetectable less than a billion years after they form. Thus, if LHS 2924 is a black dwarf, it must be young or we simply couldn't see it.

Young late-type dwarfs tend to spin faster than old late-type dwarfs. Rapid rotation causes chromospheric activity which produces hydrogen-alpha emission at a wavelength of 6563 Angstroms. The scientists looked for this Hα emission, but if it was present at all, it was very weak. This argues, on circumstantial evidence, that LHS 2924 is fairly old and thus *not* a black dwarf.

Another circumstantial way to estimate a star's age is to look at its orbital motion about the Galaxy. The youngest stars usually orbit the Galaxy in the disk very close to the galactic plane. Older disk stars also lie in the disk, but they tend to have more inclined orbits. Most halo stars, the oldest stars of all, don't even belong to the disk and have very inclined orbits.

Astronomers can derive the total space velocity of a star from its tangential velocity — motion across our line of sight — and from its radial velocity — motion along our line of sight. The tangential velocity of LHS 2924 is known from the star's proper motion and distance. Liebert and his co-workers had hoped to determine the radial velocity by looking at the Doppler shift of the Hα spectral line. But the line was too weak, and it is impossible to say whether LHS 2924 belongs to the young disk population or the old disk population. The data do, at least, suggest LHS 2924 is not a halo star.

LHS 2924, therefore, confronts us with a definite puzzle. If it's a hydrogen-burning, main sequence red dwarf, why is it so faint? On the other hand, if it's a black dwarf, why doesn't it show the Hα emission so typical of young red stars?

The astronomers note a further paradox concerning LHS 2924. The star is only about 150° K cooler than another very faint red star, VB 10 (absolute magnitude +18.7), yet the two stars' spectra are very different. In fact, the spectrum of LHS 2924 differs more from VB 10's than VB 10's spectrum differs from those of red dwarfs 500° K hotter! Why? At present, no one knows. *Ken Croswell.*

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October 19-21
Sixth Annual Custer Astronomy Club Jamboree, Southold, Long Island, New York. Contact: Warren E. Hamburger, President, 320 Asharoken Blvd., Bay Shore, NY 11706. Phone (516) 666-8654.

October 19-21
13th Annual Meeting of the Great Plains Planetarium Association, Waterloo, Iowa. Contact: Alinda Campbell, Grout Museum of History and Science, Waterloo, IA 50701.

October 24-27
Great Lakes Planetarium Association Conference, Milwaukee, Wisconsin. Contact: Gary E. Sampson, Wauwatosa West High School Planetarium, 11400 West Center St., Milwaukee, WI 53222.

October 26-27
AAVSO Fall Meeting, Salem, Massachusetts. Contact: AAVSO, 187 Concord Ave., Cambridge, MA 02138. Phone (617) 354-0484.

January 13-16, 1985
Meeting of the American Astronomical Society (professional meeting), Tucson, Arizona. Contact: AAS, 1816 Jefferson Pl. N.W., Washington, DC 20036.

February 15-17
First Annual Winter Star Party, Everglades National Park, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Richard Fagin, P.O. Box 152, Miami, FL 33197. Phone (305) 233-5165.

April 18-21
National Convention of the National Science Teachers Association, Cincinnati, Ohio. Contact: NSTA, 1742 Connecticut Ave. N.W., Washington, DC 20009.

June 28-July 1
Royal Astronomical Society of Canada General Assembly, Edmonton, Alberta, Canada. Contact: RASC, Edmonton Centre, 412 Hermitage Rd., Edmonton, Alberta, Canada T5A 3K9.

July 15-24
International Space Week '85, Cocoa, Florida. Contact: Florida Spaceweek Committee, 993 Macco Rd., Cocoa, FL 32927.

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ANNOUNCEMENT — The Quincy Astronomical Society of Quincy, Illinois, meets the fourth Friday of each month on Friend's Hill. Contact Dr. Randall McClelland at (217) 223-3902.

ANNOUNCEMENT — The Sheep Hill Astronomical Association of Boonton, New Jersey, invites all interested persons to attend its monthly meetings, held the first Sunday of every month at 7 p.m. in the Boonton High School. Contact H. Shough at (201) 697-6747.

ANNOUNCEMENT — The Northeast Kansas Amateur Astronomers League has meetings the fourth Thursday of each month at 7:30 p.m. in Room 103 of Stoffer Hall at Washburn University, Topeka, Kansas. The public is invited. For more information, phone (913) 288-2277.

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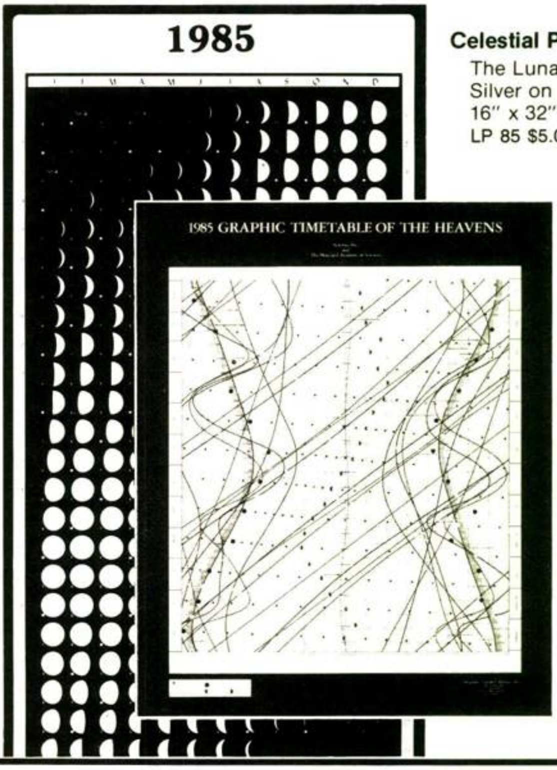

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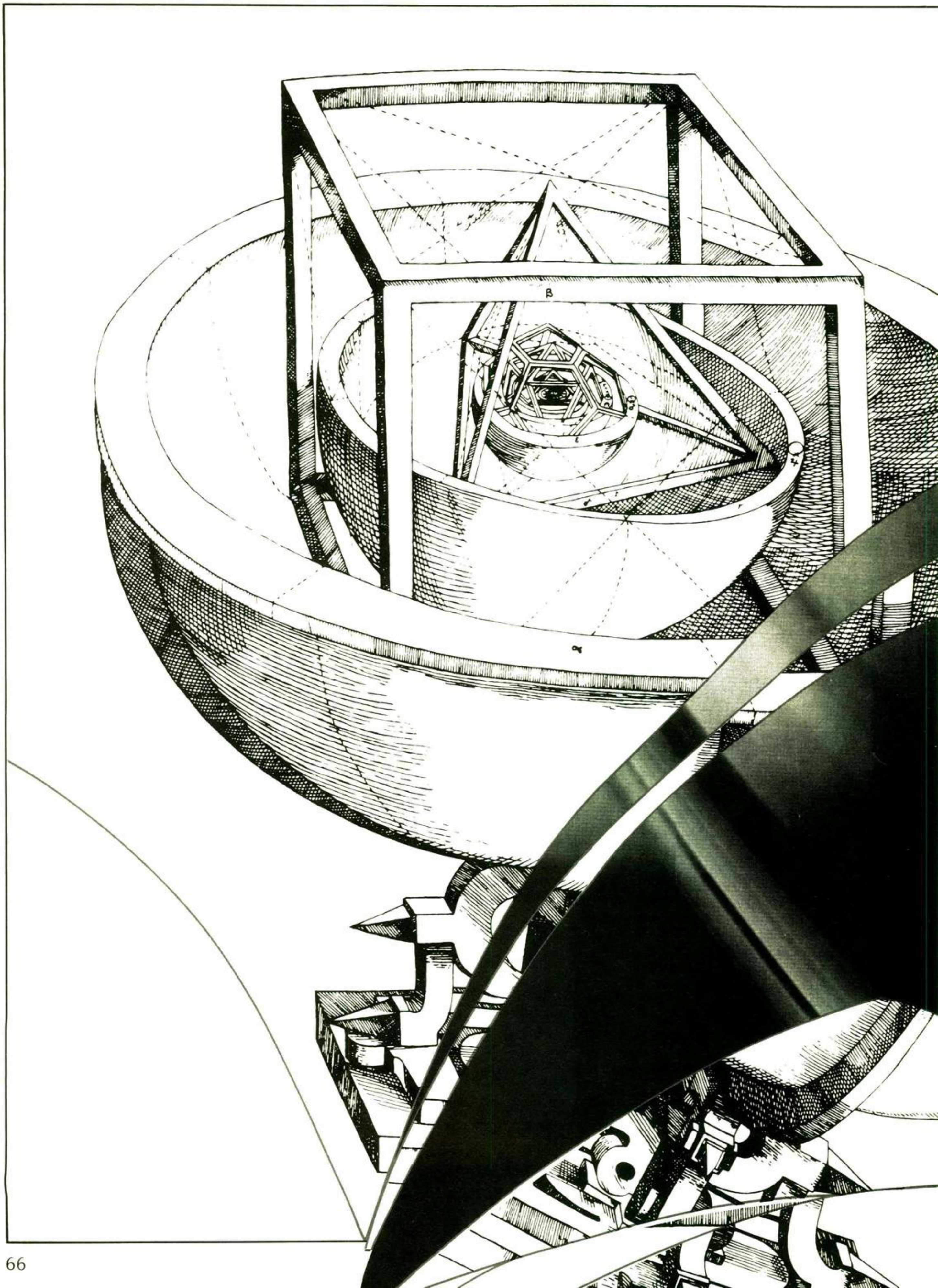
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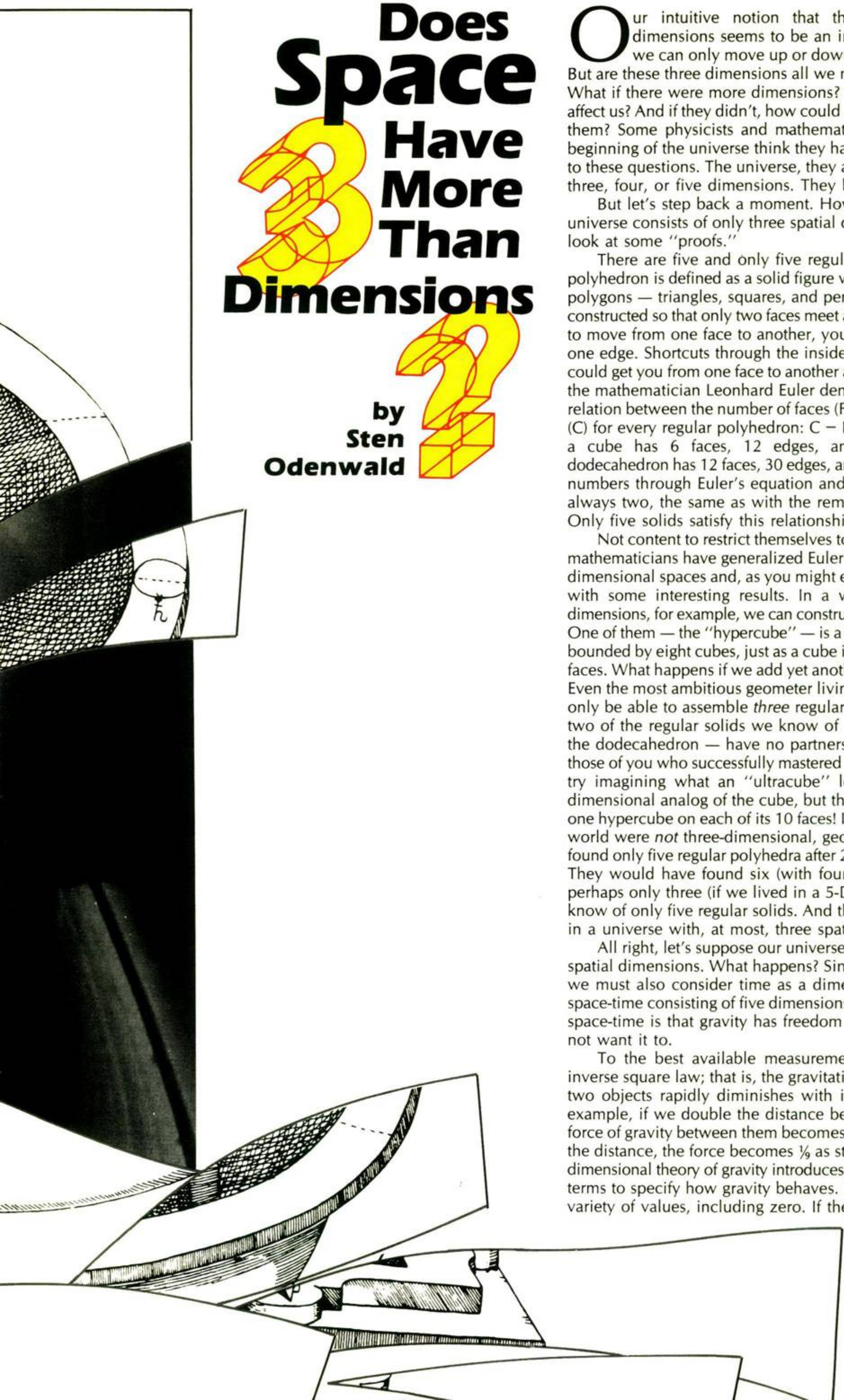
Does Space Have More Than 3 Dimensions?

by Sten Odenwald



Our intuitive notion that the universe has three dimensions seems to be an irrefutable fact. After all, we can only move up or down, left or right, in or out. But are these three dimensions all we need to describe nature? What if there were more dimensions? Would they necessarily affect us? And if they didn't, how could we possibly know about them? Some physicists and mathematicians investigating the beginning of the universe think they have some of the answers to these questions. The universe, they argue, has far more than three, four, or five dimensions. They believe it has *eleven*!

But let's step back a moment. How do we know that our universe consists of only three spatial dimensions? Let's take a look at some "proofs."

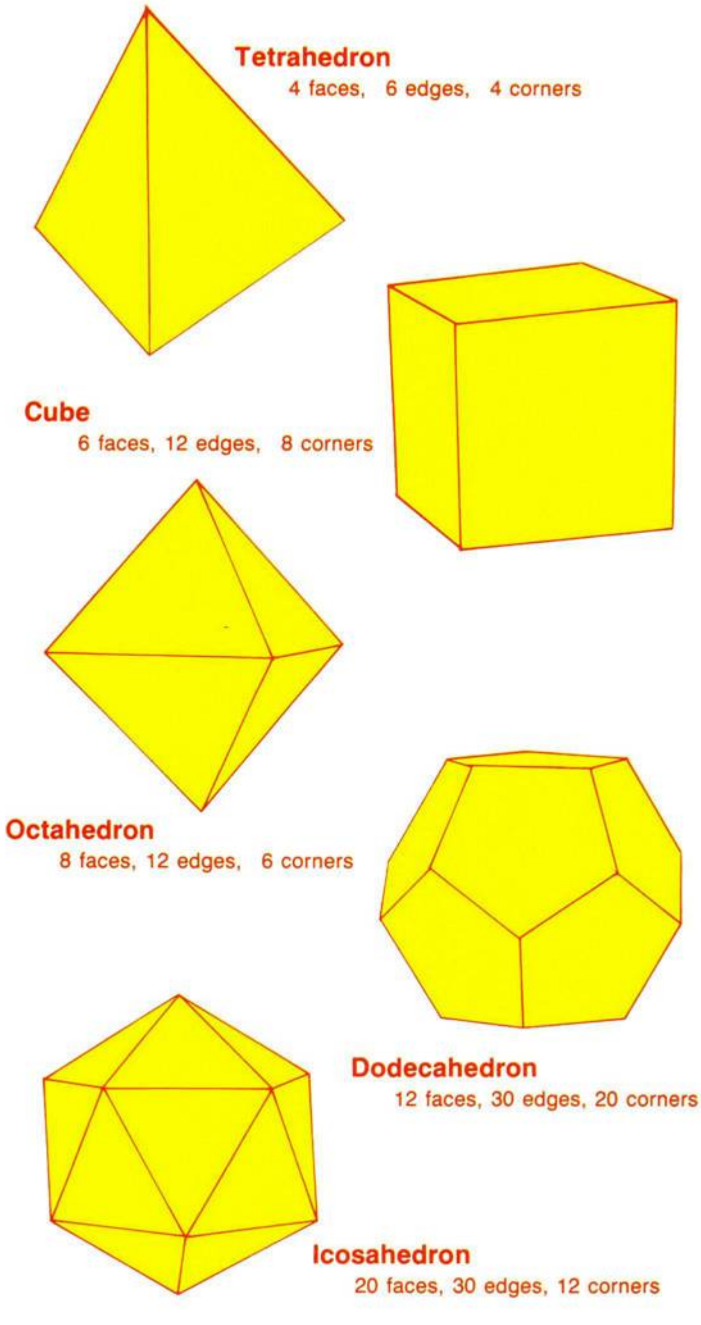
There are five and only five regular polyhedra. A regular polyhedron is defined as a solid figure whose faces are identical polygons — triangles, squares, and pentagons — and which is constructed so that only two faces meet at each edge. If you were to move from one face to another, you would cross over only one edge. Shortcuts through the inside of the polyhedron that could get you from one face to another are forbidden. Long ago, the mathematician Leonhard Euler demonstrated an important relation between the number of faces (F), edges (E), and corners (C) for every regular polyhedron: $C - E + F = 2$. For example, a cube has 6 faces, 12 edges, and 8 corners while a dodecahedron has 12 faces, 30 edges, and 20 corners. Run these numbers through Euler's equation and the resulting answer is always two, the same as with the remaining three polyhedra. Only five solids satisfy this relationship — no more, no less.

Not content to restrict themselves to only three dimensions, mathematicians have generalized Euler's relationship to higher-dimensional spaces and, as you might expect, they've come up with some interesting results. In a world with four spatial dimensions, for example, we can construct only six regular solids. One of them — the "hypercube" — is a solid figure in 4-D space bounded by eight cubes, just as a cube is bounded by six square faces. What happens if we add yet another dimension to space? Even the most ambitious geometer living in a 5-D world would only be able to assemble *three* regular solids. This means that two of the regular solids we know of — the icosahedron and the dodecahedron — have no partners in a 5-D universe. For those of you who successfully mastered visualizing a hypercube, try imagining what an "ultracube" looks like. It's the five-dimensional analog of the cube, but this time it is bounded by one hypercube on each of its 10 faces! In the end, if our familiar world were *not* three-dimensional, geometers would not have found only five regular polyhedra after 2,500 years of searching. They would have found six (with four spatial dimensions) or perhaps only three (if we lived in a 5-D universe). Instead, we know of only five regular solids. And this suggests that we live in a universe with, at most, three spatial dimensions.

All right, let's suppose our universe actually consists of *four* spatial dimensions. What happens? Since relativity tells us that we must also consider time as a dimension, we now have a space-time consisting of five dimensions. A consequence of 5-D space-time is that gravity has freedom to act in ways we may not want it to.

To the best available measurements, gravity follows an inverse square law; that is, the gravitational attraction between two objects rapidly diminishes with increasing distance. For example, if we double the distance between two objects, the force of gravity between them becomes ¼ as strong; if we triple the distance, the force becomes ⅑ as strong, and so on. A five-dimensional theory of gravity introduces additional mathematical terms to specify how gravity behaves. These terms can have a variety of values, including zero. If they were zero, however, this would be the same as saying that gravity requires only three space dimensions and one time dimension to "give it life." The fact that the Voyager space-

The Five Regular Solids


Tetrahedron
4 faces, 6 edges, 4 corners
Cube
6 faces, 12 edges, 8 corners
Octahedron
8 faces, 12 edges, 6 corners
Dodecahedron
12 faces, 30 edges, 20 corners
Icosahedron
20 faces, 30 edges, 12 corners

Leonhard Euler found that all five regular polyhedra satisfy one relationship. Pick a solid — any solid. Subtract the number of edges it has from the number of its corners. Add to your result the number of faces on the solid. The answer will be 2 for all five regular polyhedra.

craft could cross billions of miles of space over several years and arrive within a few seconds of their predicted times is a beautiful demonstration that we do not need extra-spatial dimensions to describe motions in the Sun's gravitational field.

From the above geometric and physical arguments, we can conclude (not surprisingly) that space is three-dimensional — on scales ranging from that of everyday objects to at least that of the solar system. If this were not the case, then geometers would have found more than five regular polyhedra and gravity would function very differently than it does — Voyager would not have arrived on time. Okay, so we've determined that our physical laws require no more than the three spatial dimensions to describe how the universe works. Or do they? Is there perhaps some other arena in the physical world where multidimensional space would be an asset rather than a liability?

Since the 1920s, physicists have tried numerous approaches to unifying the principal natural interactions: gravity, electromagnetism, and the strong and weak forces in atomic nuclei. Unfortunately, physicists soon realized that general relativity in a four-dimensional space-time does not have enough mathematical "handles" on which to hang the frameworks for the other three forces. Between 1921 and 1927, Theodor Kaluza and Oskar Klein developed the first promising theory combining gravity and electromagnetism. They did this by extending general relativity to five dimensions. For most of us, general relativity is mysterious enough in ordinary four-dimensional space-time. What wonders could lie in store for us with this extended universe?

General relativity in five dimensions gave theoreticians five additional quantities to manipulate beyond the 10 needed to adequately define the gravitational field. Kaluza and Klein noticed that four of the five extra quantities could be identified with the four components needed to define the electromagnetic field. In fact, to the delight of Kaluza and Klein, these four quantities obeyed the same types of equations as those derived by Maxwell in the late 1800s for electromagnetic radiation! Although this was a promising start, the approach never really caught on and was soon buried by the onrush of theoretical work on the quantum theory of electromagnetic force. It was not until work on supergravity theory began in 1975 that Kaluza and Klein's method drew renewed interest. Its time had finally come.

What do theoreticians hope to gain by stretching general relativity beyond the normal four dimensions of space-time? Perhaps by studying general relativity in a higher-dimensional formulation, we can explain some of the constants needed to describe the natural forces. For instance, why is the proton 1836 times more massive than the electron? Why are there only six types of quarks and leptons? Why are neutrinos massless? Maybe such a theory can give us new rules for calculating the masses of fundamental particles and the ways in which they affect one another. These higher-dimensional relativity theories may also tell us something about the numbers and properties of a mysterious new family of particles — the Higgs bosons — whose existence is predicted by various cosmic unification schemes. (See "The Decay of the False Vacuum," ASTRONOMY, November 1983.)

These expectations are not just the pipedreams of physicists — they actually seem to develop as natural consequences of certain types of theories studied over the last few years. In 1979, John Taylor at Kings College in London found that some higher-dimensional formalisms can give predictions for the maximum mass of the Higgs bosons (around 76 times that of the proton.) As they now stand, unification theories can do no more than predict the existence of these particles — they cannot provide specific details about their physical characteristics. But theoreticians may be able to pin down some of these details by using extended theories of general relativity. Experimentally, we know of six leptons: the electron, the muon, the tauon, and their three associated neutrinos. The most remarkable prediction of these extended relativity schemes, however, holds that the number of leptons able to exist in a universe is related to the number of dimensions of space-time. In a 6-D space-time, for example, only one lepton — presumably the electron — can exist. In a 10-D space-time, four leptons can exist — still not enough to accommodate the six we observe. In a 12-D space-time, we can account for all six known leptons — but we also acquire two additional leptons that have not yet been detected. Clearly, we would gain much on a fundamental level if we could increase the number of dimensions in our theories just a little bit.

How many additional dimensions do we need to consider in order to account for the elementary particles and forces that we know of today? Apparently we require at least one additional spatial dimension for every distinct "charge" that characterizes how each force couples to matter. For the electromagnetic force, we need two electric charges: positive and negative. For the strong force that binds quarks together to form, among other things, protons and neutrons, we need three "color" charges — red, blue, and green. Finally, we need two "weak" charges to account for the weak nuclear force. If we add a spatial dimension for each of these charges, we end up with a total of seven extra dimensions. The properly extended theory of general relativity we seek is one with an 11-dimensional space-time, at the very least. Think of it — space alone must have at least 10 dimensions to accomodate all the fields known today.

Of course, these additional dimensions don't have to be anything like those we already know about. In the context of modern unified field theory, these extra dimensions are, in a sense, internal to the particles themselves — a "private secret," shared only by particles and the fields that act on them! These dimensions are not physically observable in the same sense as the three spatial dimensions we experience; they stand in relation to the normal three dimensions of space much like space stands in relation to time.

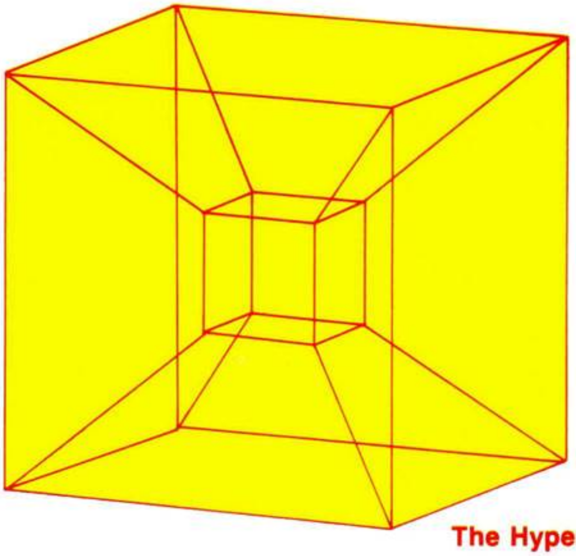
With today's veritable renaissance in finding unity among the forces and particles that compose the cosmos, some by methods other than those we have discussed, these new approaches lead us to remarkably similar conclusions. It appears that a four-dimensional space-time is simply not complex enough for physics to operate as it does.

We know that particles called bosons mediate the natural forces. We also know that particles called fermions are affected by these forces. Members of the fermion family go by the familiar names of electron, muon, neutrino, and quark; bosons are the less well known graviton, photon, gluon, and intermediate vector bosons. Grand unification theories developed since 1975 now show these particles to be "flavors" of a more abstract family of superparticles — just as the muon is another type of electron. This is an expression of a new kind of cosmic symmetry — dubbed supersymmetry, because it is all-encompassing. Not only does it include the force-carrying bosons, but it also includes the particles on which these forces act. There also exists a corresponding force to help nature maintain supersymmetry during the various interactions. It's called supergravity. Supersymmetry theory introduces two new types of fundamental particles — gravitinos and photinos. The gravitino has the remarkable property of mathematically moderating the strength of various kinds of interactions involving the exchange of gravitons. The photino, cousin of the photon, may help account for the "missing mass" in the universe.

Supersymmetry theory is actually a complex of eight different theories, stacked atop one another like the rungs of a ladder. The higher the rung, the larger is its complement of allowed fermion and boson particle states. The "roomiest" theory of all seems to be SO(8), (pronounced ess-oh-eight), which can hold 99 different kinds of bosons and 64 different kinds of fermions. But SO(8) outdoes its subordinate, SO(7), by only one extra dimension and one additional particle state. Since SO(8) is identical to SO(7) in all its essential features, we'll discuss SO(7) instead. However, we know of far more than the 162 types of particles that SO(7) can accommodate, and many of the predicted types have never been observed (like the massless gravitino). SO(7) requires seven internal dimensions in addition to the four we recognize — time and the three "every day" spatial dimensions. If SO(7) at all mirrors reality, then our universe must have at least 11 dimensions! Unfortunately, it has been demonstrated by W. Nahm at the European Center for Nuclear Research in Geneva, Switzerland that supersymmetry theories for space-times with more than 11 dimensions are theoretically impossible. SO(7) evidently has the largest number of spatial dimensions possible, but it still doesn't have enough room to accommodate all known types of particles.

It is unclear where these various avenues of research lead. Perhaps nowhere. There is certainly ample historical precedent for ideas that were later abandoned because they turned out to be conceptual dead-ends. Yet what if they turn out to be correct at some level? Did our universe begin its life as some kind of 11-dimensional "object" which then crystallized into our four-dimensional cosmos?

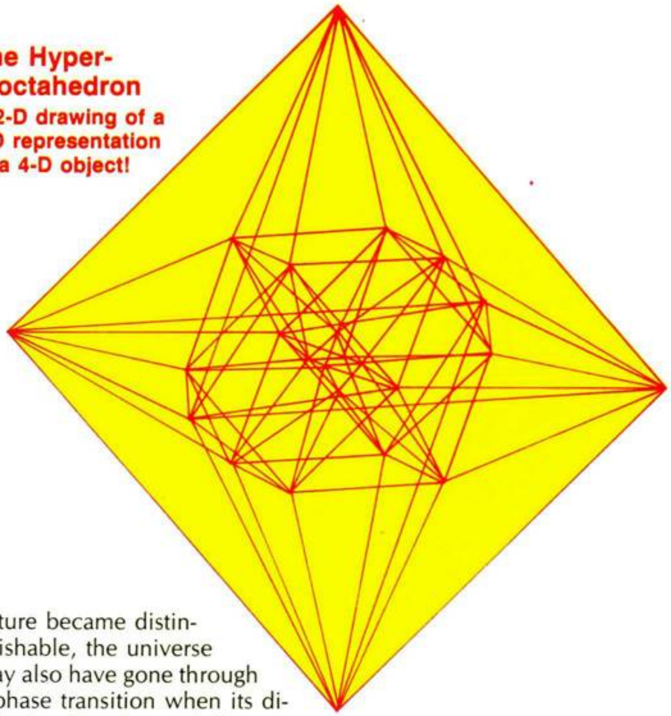
Although these internal dimensions may not have much to do with the real world at the present time, this may not always have been the case. E. Cremmer and J. Scherk of l'Ecole Normale Superieure in Paris have shown that just as the universe went through phase transitions in its early history when the forces of nature became distinguishable, the universe may also have gone through a phase transition when its dimensionality changed. Presumably matter has something like four external dimensions (the ones we encounter every day) and something like seven internal dimensions. Fortunately for us, these seven extra dimensions don't reach out into the larger 4-D realm where we live. If they did, a simple walk through the park might become a veritable obstacle course, littered with wormholes in space and who knows what else!



The Hypercube

The Hyper-octahedron

A 2-D drawing of a 3-D representation of a 4-D object!



Alan Chocos and Steven Detweiler of Yale University have considered the evolution of a universe that starts out being five-dimensional. They discovered that while the universe eventually does evolve to a state where three of the four spatial dimensions expand to become our world at large, the extra fourth spatial

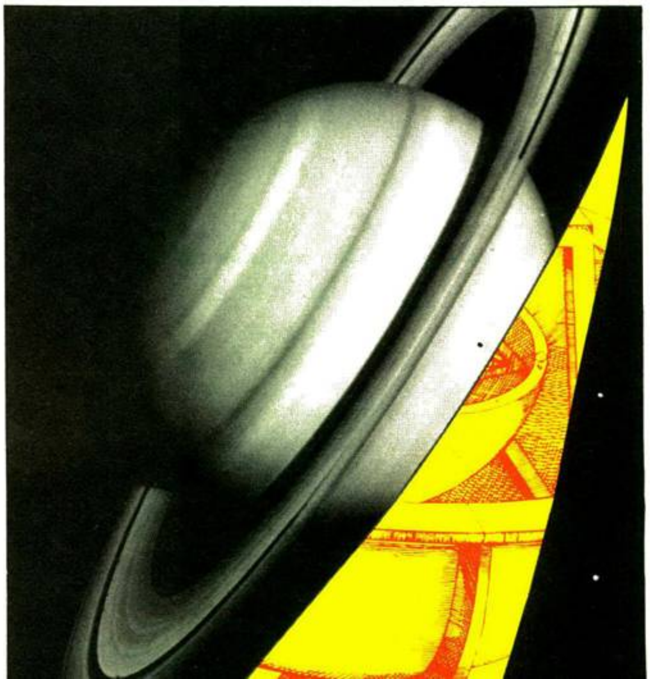
Dimensions in the Universe

Number of Spatial Dimensions in Universe	Number of Possible Geometric Solids	Physical Properties	Theoretical Predictions	
			Sypersymmetry Theory	Number of Possible Particle States
1	Line	Curved space, gravity, and electromagnetic radiation are impossible.	None	None
2	5 regular polygons	Gravity cannot act over great distances. Electromagnetic radiation exists, but acts in unusual ways. For example, short pulses — such as Morse code signals — get spread out over a long time. A signal lasting just $1/_{10}$ of a second in our world could take several hours to fade out in a 2-D cosmos. Also, electric charges do not obey an inverse-square ($1/_{r^2}$) law. They follow a $1/_r$ law instead.	None	None
3	5 regular polyhedra	Gravity acts out to infinity. Both gravity and electromagnetic radiation follow $1/_{r^2}$ law.	None	None
4	6 regular polyhedra	Gravity and electromagnetism *can* act normally, but they are also free to work in ways we do not observe. This is still unexplored territory.	SO(1) Has one "internal" dimension.	2
5	3 regular polyhedra	"	SO(2) Has two internal dimensions.	4
6	"	"	SO(3)	8
7	"	"	SO(4)	17
8	"	"	SO(5)	37
9	"	"	SO(6)	79
10	"	"	SO(7)	162
11	"	"	SO(8) Contains eight internal dimensions, but yields only one additional particle state. In essential features it is identical to SO(7).	163

For more than 9 internal dimensions, supergravity theories are probably impossible. Some other approach must be used.

dimension shrinks to a size of 10^{-31} centimeter by the present time. The fifth dimension to the universe has all but vanished and is 20 powers of 10 — 100 billion billion times — smaller than the size of a proton. Although the universe appears four-dimensional in space-time, this perception is accidental due to our large size compared to the scale of the other dimensions. Most of us think of a dimension as extending all the way to infinity, but this isn't the full story. For example, if our universe is really destined to re-collapse in the distant future, the three-dimensional space we know today is actually limited itself — it will eventually possess a maximum, finite size. It just so happens that the physical size of human beings forces us to view these three spatial dimensions as infinitely large. It is not too hard to reconcile ourselves to the notion that the fifth (or sixth, or eleventh) dimension could be smaller than an atomic nucleus — indeed, we can probably be thankful that this is the case.

Sten Odenwald is an infrared astronomer at the Naval Research Laboratory in Washington, D.C. His research interests include studies of the far-infrared properties of giant molecular clouds and young star-forming regions in the Galaxy. His last ASTRONOMY *article, "Astronomical Ballooning," appeared in the August 1984 issue.*



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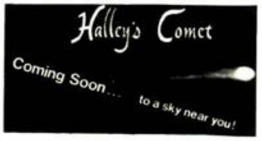
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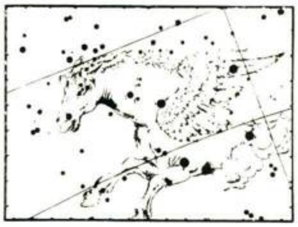

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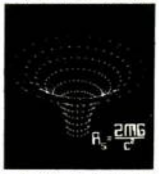
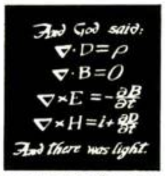
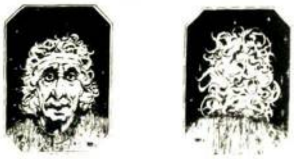
PEGASUS. From Johann Bayer's Star Atlas *Uranometria* published in 1603. On lt. blue, silver, or lilac shirts.




And God said:
$\nabla \cdot D = \rho$
$\nabla \cdot B = 0$
$\nabla \times E = -\frac{\partial B}{\partial t}$
$\nabla \times H = i + \frac{\partial D}{\partial t}$
And there was light.

5

Front: Black hole w/ Schwartzchild's radius.
Back: Maxwell's equations of light.



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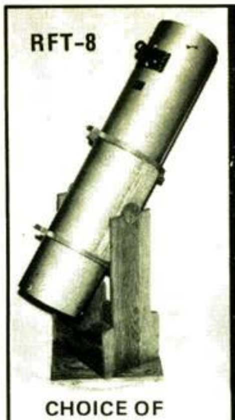

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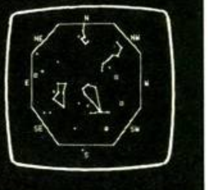

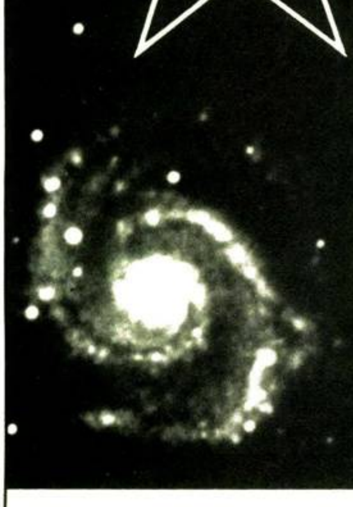

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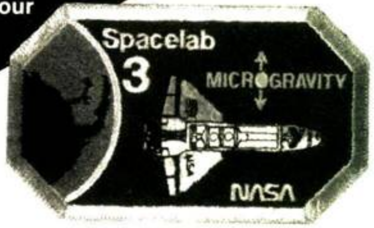

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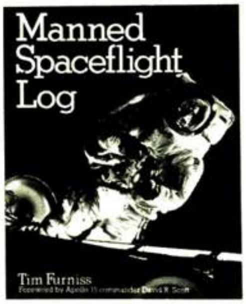

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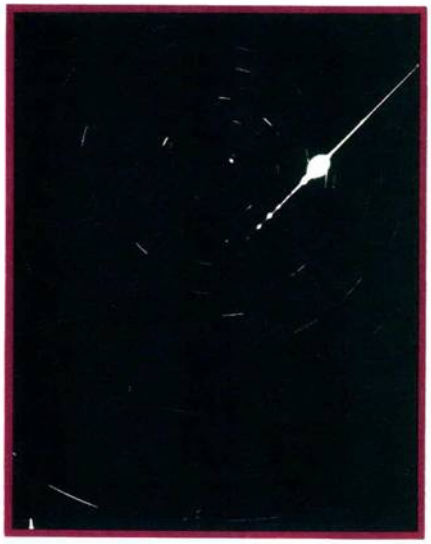
Photographing Meteors in Winter

Photography in Astronomy

Whenever you think of meteor showers, do you find yourself thinking "late summer"? It's natural to do. This is when the famed Perseids reach their peak activity, witnessed by many people vacationing far from the grey skyglows of "urbia" and suburbia. But there's a lot more to meteor watching and photographing than just this one shower, and it's silly not to explore what other seasons have to offer. Try it once or twice and you'll be among that select fraternity who can say — somewhat smugly — that while the Perseids are all right as meteor showers go, they are far from being the sky's richest display.

Basic gear for meteor photography is almost identical to what you'd use for star trails or constellation portraits. In essence, you'll need a camera that can take long exposures, a fast lens, and fast film. Let's look at each of these in a little more detail.

The camera is the basic ingredient, but there are cameras and there are *cameras*. The crucial feature yours must have is the ability to take long time exposures. Unfortunately, you can't automatically assume this, even with a top-name model. In response to public demand for lightweight, small cameras at low prices, many bottom-of-the-line and mid-range 35mm cameras have gone all-electronic and are totally dependent on batteries. This causes no problems when you're shooting cloud shadows in the Grand Canyon on a warm day at f/11 and 1/125, but it can raise difficulties at 3 a.m. on a cold December morning for 30 minute exposures.



A magnitude −10 fireball cutting across polar star trails was caught using a 53mm f/2.8 lens on Fortepan Rapid (ISO 200) film by Peter Zana of Budapest, Hungary.

Batteries lose their punch when you make long, uninterrupted demands on them or when they are chilled. Meteor photography, especially at this time of year, can do both simultaneously! Therefore, check the fine print in your owner's manual to see how the camera handles long (half-hour to one-hour) exposures. Some cameras use a mechanical control for the B or T setting, thus avoiding the problem completely, while others need electricity only when opening and closing the shutter. But a few models use batteries to hold the shutter open, draining them steadily all during the exposure — a disastrous piece of design. If your camera falls into this last category, meteor photography (and much general astrophotography) is virtually closed to you until you get a different camera.

Now let's look at the business end of the camera — its lens. Since you can't tell when or where a meteor will streak, you want to cover as much of the sky as you can in each frame. This calls for one thing: a wide-angle lens. Beginners sometimes feel tempted to "go the ultimate" and use a fish-eye, but fish-eye lenses seldom produce very good results on meteors. Why? A fish-eye covers the entire sky, but they often have very small apertures and hence collect little light. This hardly matters for daylight photography, but if you want to catch meteors, it's far too slow.

A second factor also comes into play: the meteor's size on film. Squeezing an entire celestial hemisphere onto one-and-a-half square inches means that any meteor streak you record will be awfully small on the film. Granted, you might catch that sky-spanning "fireball of the century," but using a fish-eye as your one-and-only lens is relying a bit too heavily on Lady Luck.

If fish-eye lenses are too slow, then how slow is acceptable? That depends on several factors, including sky brightness, speed of film, and whether the camera is on a tripod or riding piggyback on a telescope. In general, a lens slower than f/4 is too slow to catch anything but the brightest meteors, and that's already assuming you have 400- or 1000-speed film in the camera. As a rule of thumb, go for sky coverage up to the point where the lens you've chosen is slower than f/4, then sacrifice coverage for lens speed.

What about zooms? Optically, zoom lenses have become a lot better in recent years; in fact, many photographers now use a 35-75mm zoom as their normal lens. The chief drawback to zooms in meteor photography is that they run at least one stop slower than a prime lens of fixed focal length. In practical terms, this means you photograph fewer meteors — all else being equal — and that's the "bottom line" for most astrophotographers.

Before we discuss film, let's examine a few accessories. First on our list is a cable release that locks. If you have one, bring it; if you don't, buy one. And get a release that's longer than six inches — a one-foot model is much easier to use.

Next you'll need a lens shade or hood. It doesn't matter how wide-angle your lens is; get the proper hood and use it. Besides preventing stray light from accidentally hitting the lens, a hood also acts as a dew-cap to slow the deposit of dew or frost on the outer surface of your lens.

Tripods — use your best; if it's a little shaky, suspend something fairly heavy low to the ground from the center post to stabilize it. (Later, when we cover actual picture taking, we'll mention a way to avoid shake when you trip the shutter.)

Some meteor photographers like to place their cameras piggyback on a telescope with an equatorial mounting, and track on the stars. This nets you nice starfield photos even if you don't catch a meteor. It adds to the burden of set-up, but if you're used to making dark-sky expeditions with your scope, you probably have a routine down pat.

One last accessory always raises the eyebrows of neophyte astrophotographers, but gets a smile from case-hardened veterans: a hair dryer. Dew and frost are facts of life for nighttime photographers and if you don't take steps to combat them, you'll find your observing session forced to an early close when your lens frosts over. While observing, every now and then gently run your bare fingers over an exposed metal surface, such as a car fender. If it feels damp or has a cold, dry stickiness, you've got an imminent problem. Use the hair dryer to direct a flow of warm — or at least dry — air across the lens for a few minutes. Don't let the camera "see" the dryer's glowing heat coils; blow the air in from the side. Depending on conditions, you may have to do this just a few times a night or almost continually.

Some photographers wrap the lens in heat tape which is used for thawing frozen pipes. Get tape that does not have an automatic thermostat; a power rating of one to five watts is adequate. Wrapping the camera body with heat tape is also a good idea when conditions are extremely cold. Chilled film becomes brittle and can snap or tear if you try to wind it quickly — a good reason to leave those motor drives at home, too. If it's very cold and you suspect the film may shatter upon winding, warm up the camera in a heated car before you crank the lever.

Meteor photos have been taken on just about every kind of film imaginable. If you have a favorite, go ahead and use it (though if it's Kodachrome 25, you'd better pick something faster). Your choice of film is determined by what kind of results you want and how much of a home darkroom you have. The more you can do yourself, the less you need to worry about choosing a film that photofinishers can't bungle.

Slide films are safest from this point of view and you've got good choices — especially with the films Kodak, Fuji, Agfa, and 3M offer in the ISO 1000+ class. The slower 400- and 200-speed transparency films are pretty good, too. Whatever film you use, start each roll with one normal daylight photo. This allows the finisher's automatic slide mounting equipment to adjust the spacing properly. (You can also request that the roll be left unmounted and do it yourself.)

Prints provide the most flexibility and variety for display and VR 1000 is a good print film. But a big problem is that commercial photofinishers don't print astro-negatives very well. Finding a local custom printer can be difficult and expensive, although this service exists in most large cities. Some photographers have achieved good results using ordinary printers by insisting on a DARK, DARK, DARK background, and others have found "Speedee 1-Hour Photoprint" shops quite amenable to special requests. After all, you can usually talk to the person who makes the prints — and that's more than Kodak offers.

Most black and white astrophotos are taken by people who have their own darkrooms. In many ways, black and white is best to use. True, you won't get those pretty, subtle colors in your star trails or meteors, but you won't have to mess around with keeping the background color balance realistic, either. You can take your film and soup it in warm Dektol if you really want to push the film for all it's worth!

In any case, black and white offers a lot of options, from the old standby Tri-X to the newer Technical Pan 2415, which has virtually taken over the field of black and white astrophotography. As Kodak makes it, 2415 is contrasty, virtually grainless, and slow — too slow, in fact, for most celestial subjects. How do astrophotographers use it, then? They carefully de-stabilize the film's emulsion — hypersensitize it — with forming gas, a mix of 8 percent hydrogen and 92 percent dry nitrogen. You can buy rolls of 2415 already "hypered," or you can buy a hypering kit that consists of a small gas chamber, vacuum pump, connectors, and a refillable tank of gas. (For suppliers, see the ads in ASTRONOMY.)

You don't *have* to use 2415. In fact, it's not commonly available in photo stores, uses a somewhat unusual developer, and needs hypering to kick it into high gear. It's more trouble than many beginners want to bother with. If you want convenience, then get Tri-X, Plus-X, or the similar films by Ilford or Agfa.

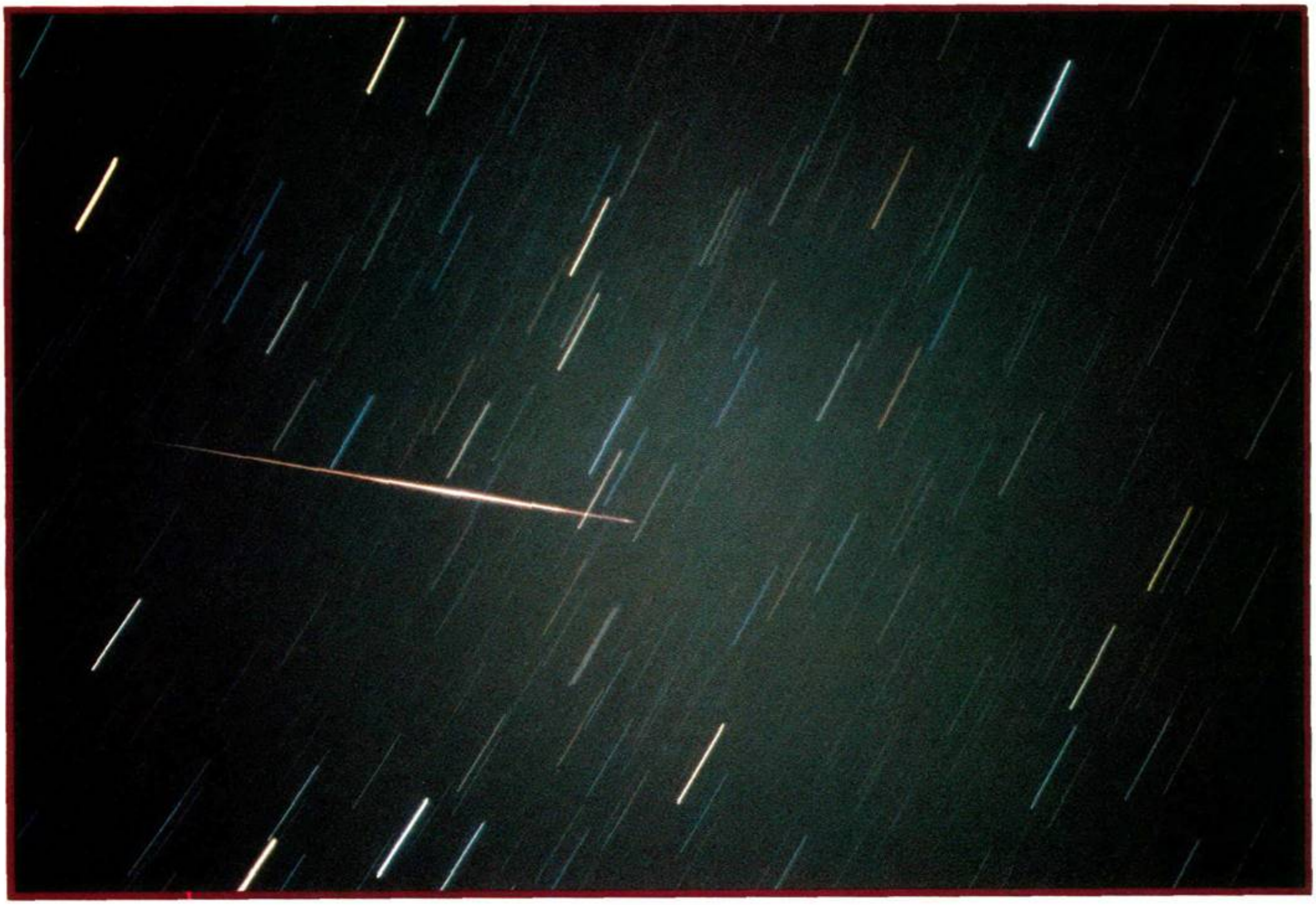
At this point, your photographic outfit is ready to use. Now, what are you going to photograph? Look in the table below for the meteor shower nearest to now, and get out your state or provincial road map. Most of us live in or near cities and, while we could observe from our own backyard, a trip to view dark country skies is a lot more fun — although it calls for more planning.

Meteors are not as hard to see as the "faint fuzzies" beloved by deep-sky aficionados, so you don't have to search far and wide for skies that are blacker-than-

Meteor Showers of Late Fall and Winter

Shower Name	Peak Date	Active Dates	Radiant	Moon Age At Peak	ZHR	Velocity (km/sec)	Notes
*S. Taurids	Nov. 5	mid-Sept. - mid Dec.	3h 32m +14°	12d	15	30	bright, with many fireballs
Cepheids	9	early November	23h 30m +63°	16	5?		little known, sparse
Alpha Pegasids	12	late Oct. - mid Nov.	22h 50m +20°	19		10-15	very slow and sparse
*Andromedids	14	late Aug. - late Nov.	1h 40m +44°	20	10?	20	faint, some colored
*Leonids	17	mid November	10h 08m +22°	23	10?	71	great numbers at 33-year intervals
Monocerotids	Dec. 10	late Nov. - mid Dec.	6h 50m +10°	17		42	little observed
Chi Orionids	10	early December	5h 36m +20°	17			little observed
Sigma Hydrids	11	early December	8h 32m + 2°	18	5	58	fast
*Geminids	13	mid December	7h 28m +32°	20	50	35	often colored
Omicron Piscids	16	mid December	1h 42m + 9°	23	5	25	faint
Delta Arletids	20	mid December	3h 35m +25°	27		15	slow, sparse
*Ursids	22	late December	14h 28m +78°	29	10	33	good chance to observe
Lyncds	28	late December	7h 15m +36°	6			little observed
*Quadrantids	Jan. 3	early January	15h 28m +50°	11	50	42	very narrow peak
Delta Cancrids	15	mid January	8h 24m +20°	23	3		very sparse
Coma Berenicids	17	mid January	12h 30m +19°	25	1	64	swift
Alpha Aurigids	Feb. 5	late Jan. - mid Feb.	4h 56m +43°	15	12		slow
Delta Leonids	25	early Feb. - mid Mar.	10h 36m +19°	6	3	24	sparse, slow shower

*best showers; ZHR is zenithal hourly rate — what a sharp-eyed observer would see under ideal conditions if the radiant were directly overhead.



This Perseid was captured with a 50mm f/1.4 lens in a 10-minute exposure on Ektachrome 400 film. Tim Pickering photo.

black. Take the radiant's celestial position as shown in the table and check with a planisphere (or computer program) to see what parts of the sky the radiant will move through during the night. Then, head away from the city toward the radiant. This will keep the urban glow as nearly opposite the radiant as possible. How far do you have to go? If you can make out the Milky Way, you've gone far enough.

The season is late fall/early winter, so some thoughts about keeping warm are necessary. Once again, veterans will have developed their own tried-and-true systems, but beginners often become uncomfortably cold on their first few observing trips. A good rule is to wear full winter outdoor gear for your part of the country. Remember, you are going to be outside and sedentary for many hours. Bring a lawn chair, sleeping bag or blankets (and perhaps a Mylar "space blanket"), a backpacker's sleeping pad, and many layers of warm clothing. It's better to bring too many items than too few — but don't wear so much that your blood circulation is constricted.

Besides photo equipment and warm clothing, some useful miscellaneous items include handwarmers, red-lensed flashlights, a log book (or tape recorder), a star atlas, and binoculars. Some people bring along a small telescope for stargazing while their camera exposures are running. Many observers find that meteor watching is a fine occasion for a group expedition. Having extra people along helps to keep everyone awake and makes the night pass more quickly.

Setting up and aiming your camera isn't quite as simple as it looks. Meteors in a shower all appear to come from the shower's radiant. In reality, the meteors are all traveling parallel to each other, but perspective gives them the appearance of diverging as they streak into the atmosphere. If you point your camera directly at the radiant, the few meteors you capture will have short, minimal trails. You'll do much better if you aim somewhat off the radiant — about 45° to 60° away from it. This is the best overall compromise between getting a long trail and letting the meteors spread out too thinly.

How long to expose depends on your lens, film, and the sky brightness at the site. If possible, try to estimate exposure time from your previous experience with the film. Failing that, 10 to 15 minutes is probably long enough with ISO 1000 film at f/2 on a moonless night. Running longer will cause sky fog problems. Slower films or lenses will let you expose longer, although they won't record objects which are faint. Piggybacking the camera on a telescope makes stars appear brighter since they stay in one place on the film, building up exposure. Stellar backgrounds, therefore, go several magnitudes fainter than when you let the stars trail. (Meteors are unaffected and record identically in both methods, since they are rapidly-moving streaks no matter what.)

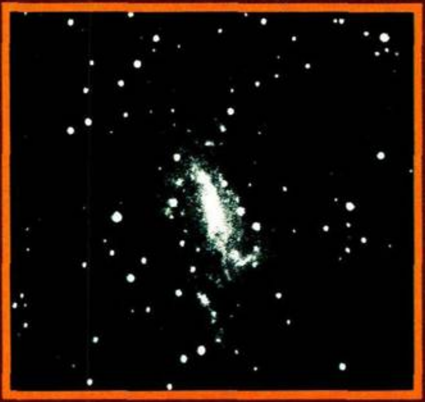
Making the exposure is quite simple: erect the tripod, attach the camera, fit the cable release, screw on the lens hood, set the shutter to B or T, focus to infinity, open the lens to the lowest f/stop, aim where you feel lucky, and fire away! Experienced astrophotographers often place a piece of black cardboard over the lens before they open the shutter, moving it away to begin the exposure after the shutter and mirror vibrations have died out. Be sure to record the starting time (and later, the finish time) in your logbook, together with the region of sky you photographed.

* * * * *

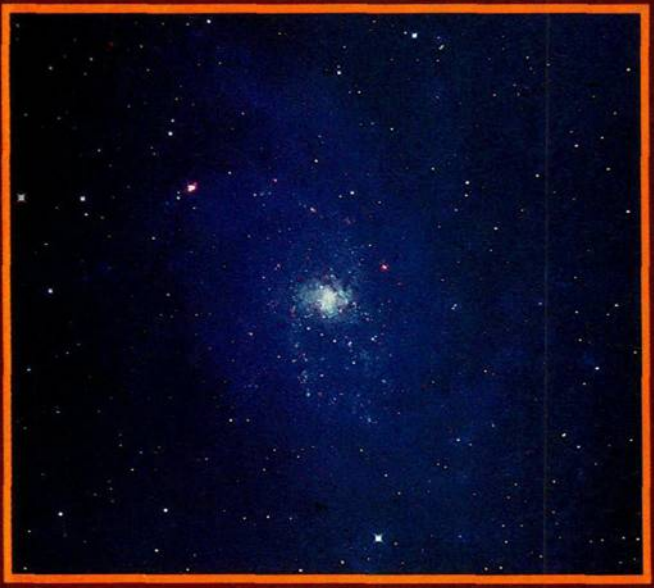
By the time dawn or moonrise rolls around and it's time pack up, you stretch stiffly, rub your gritty-feeling eyes, and stamp some sensation back into your feet. Well, that's that, you think. If Lady Luck smiled on me, there'll be at least one meteor somewhere on that roll of film. Say, didn't somebody once calculate it takes 50 frames to nab one meteor? Hah! That miserable pessimist have been using Kodachrome 25 at f/11. I *know* I did better than that . . . .

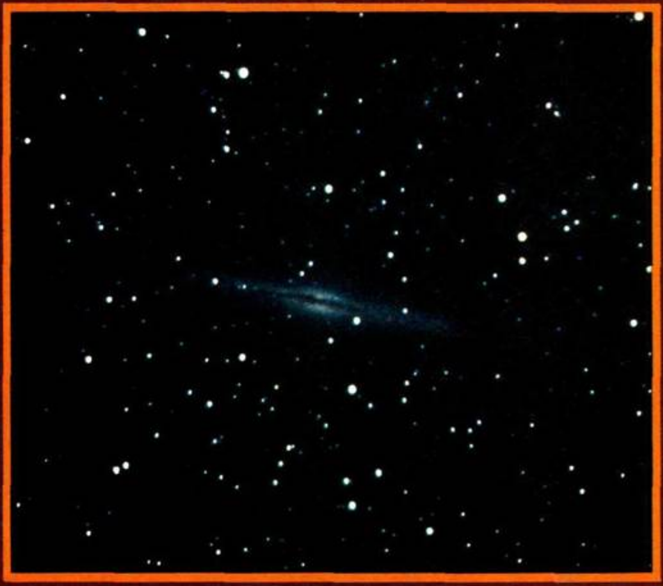
Hey, friend, when's the next shower due?

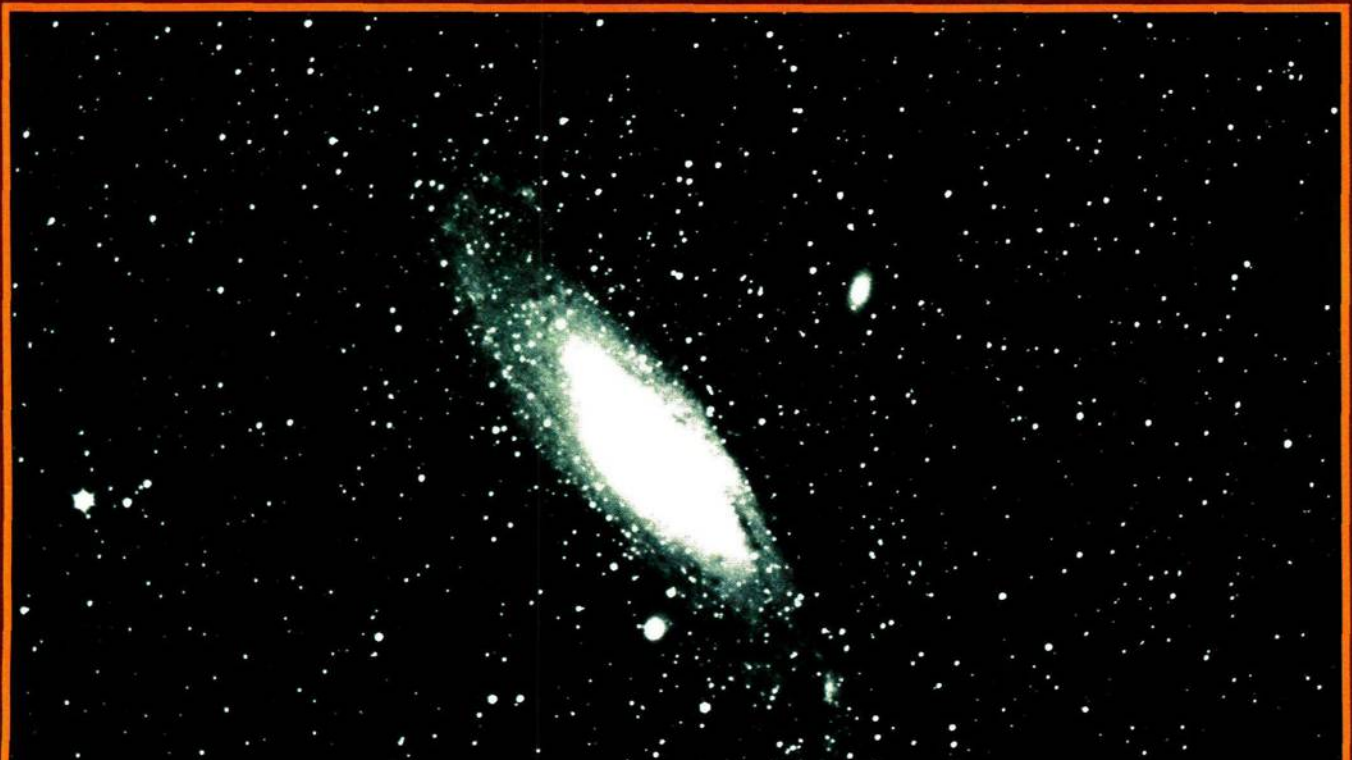
— *Robert Burnham*



Far left: Planetary nebula NGC-7662, shown here as an overexposed "star," appears as a double-ringed shell of nebulosity in large backyard scopes. Photo by Martin C. Germano. Left: Galaxy NGC-925 in Triangulum has knotty, dusty arms. Photo by K.A. Brownlee. Below left: Although M-33 has a reputation for being elusive, it is easily visible under dark skies. Photo by Ron Royer. Below right: NGC-891, one of the sky's best edge-on spirals. Photo by Bill Iburg. Bottom: M-31, the Andromeda Galaxy, is our "sister spiral" in the Local Group — it reveals a wealth of detail under dark skies. Photo by *Martin C. Germano*.







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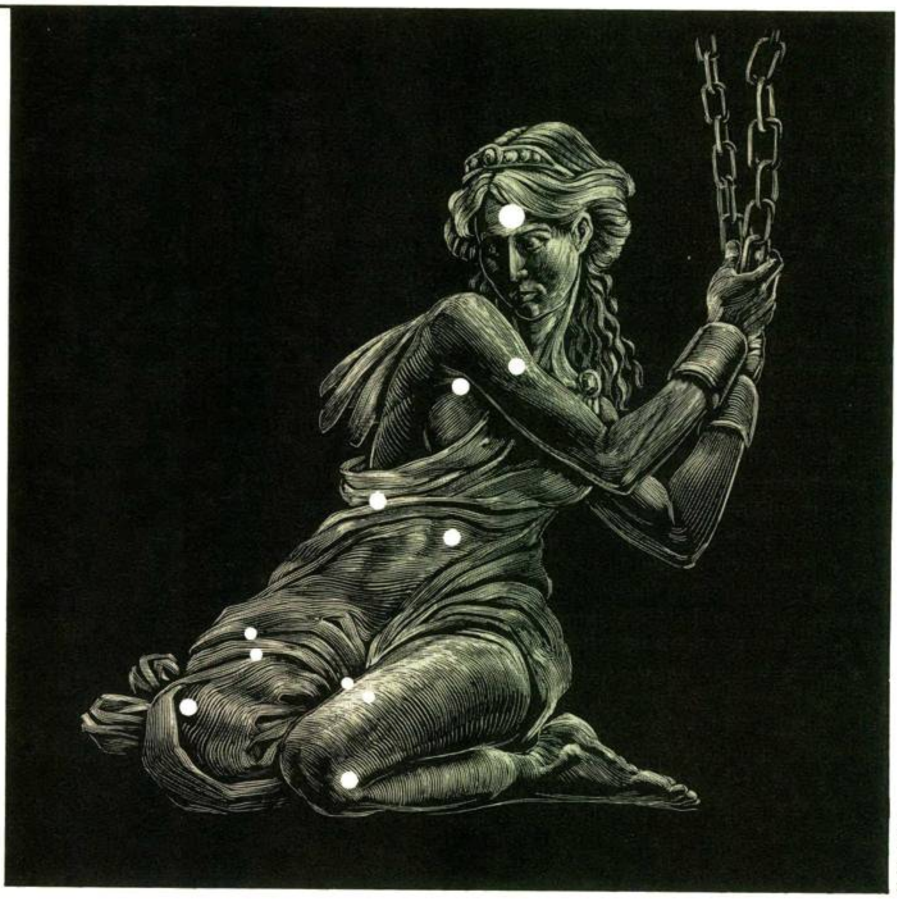
Triangulum

Tri
Trianguli



Keith Ward

The constellations **Andromeda** and **Triangulum** do not contain many bright deep-sky objects, as they lie away from the plane of the Milky Way; they mainly feature faint galaxies. Two spirals in this region of sky, however, are the brightest and largest members of the Local Group of galaxies — the home cluster **M-31** in Andromeda and M-33 in Triangulum.

With a total magnitude of 3.5, M-31 (NGC-224), known as the Andromeda Galaxy, is the brightest spiral galaxy in the sky, visible without optical aid as a fuzzy patch spanning 3°. Easy to find about 1° west of Nu (ν) Andromedae, M-31 is our "sister spiral" in the Local Group. It contains 300 billion stars whose combined mass might well total over one trillion suns. The galaxy lies some 760 kiloparsecs away and measures 55 kiloparsecs across; we could fit a dozen M-31s end-to-end between the great spiral and our own Milky Way.

M-31's light is unevenly distributed across its surface, the brightest part being the galaxy's yellowish core — easily visible in binoculars and finder telescopes as an elongated streak of light. This nuclear bulge represents the inner few kiloparsecs of M-31; most of the galaxy has a much lower surface brightness and is more difficult to see. A 6-inch telescope shows a large, extended outer halo of greyish nebulosity surrounding this bright core. The light comes from millions of relatively young stars held in M-31's spiral arms. An 8-inch scope on a dark night reveals two parallel dust lanes alongside the southern edge of the galaxy's core, and a knotty bright patch of nebulosity near M-31's southwestern tip is NGC-206 — a huge starcloud in one of the galaxy's spiral arms. Used at high power, 10-inch telescopes show the core of M-31 to be star-like.

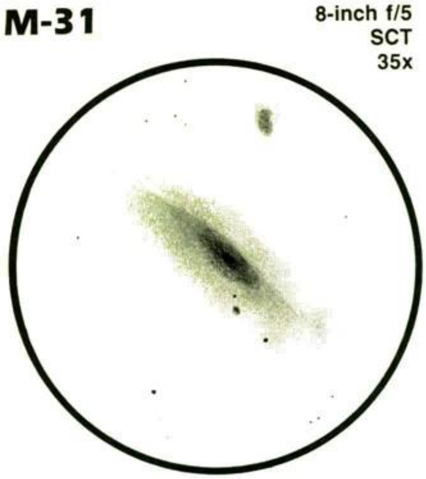
If you look at M-31 with a low-power eyepiece, you'll see two small fuzzy patches within the same field of view as the nucleus. These are **M-32** (NGC-221) and **NGC-205**, two elliptical satellite galaxies located roughly five and seven kiloparsecs from M-31, respectively. M-32 shines at magnitude 8.2 and measures some 8′ x 6′ across, giving it an average surface brightness of 12.3 magnitudes per square arc-minute. NGC-205 has a higher total magnitude but measures 17′ x 10′, yielding a much fainter surface brightness of 13.6. In comparison, the tenuous spiral arms of M-31 have a surface brightness of 13.4. M-32 appears as a small, glowing, condensed ball of light with a notably brighter center in most telescopes. In a 6-inch scope, NGC-205 looks like a large oval nebulosity, slightly brighter in the center and very diffuse and unconcentrated near its edges. M-31 contains two other elliptical satellites: NGC-147 and NGC-185. They are located about 90 kiloparsecs from M-31 and lie some 7° north in Cassiopeia.

After the M-31 group, Andromeda's next easiest galaxy to find is **NGC-404**, a small roundish lenticular located 6′ northwest of the second-magnitude star Beta (β) Andromedae. NGC-404 measures 1.3′ x 1.3′ wide and glows at magnitude 11.9. Although its surface brightness is high, proximity to Beta makes it difficult to locate on less-than-dark nights. Try a 6-inch at low-power; after you find the galaxy, switch to high power and move Beta slightly out of the field. This will help you see the feeble light from the galaxy.

Another galaxy to look for is the faint, edge-on spiral **NGC-891**. This lies halfway between the bright double star Gamma (γ) Andromedae and the glowing open cluster M-34 in Perseus. It shines at magnitude 10.0 and covers a sky area of 12′ x 1′; its low surface brightness makes it difficult to spot in 3-inch and 4-inch telescopes. A good 6-inch scope shows a thin spindle of nebulosity spanning about 10′, a bright central bulge, and a narrow dust lane bisecting NGC-891's long axis. NGC-891 belongs to the NGC-1023 group of galaxies, a cluster some 13 megaparsecs distant. The group contains NGC-891, NGC-1023, and the dusty Sc-type spiral NGC-925 in Triangulum.

NGC-7640 is a dim Sb-type spiral — a challenging object for 4-inch scopes under dark skies. It is a good example of a nearly edge-on galaxy and distributes its 12.5 magnitude glow over a 9.0′ x 1.0′ area. An 8-inch telescope shows NGC-7640 as a slender, even nebulosity with a bright bulge centered on the galaxy's nucleus. A 17.5-inch telescope reveals that the pancake-shaped nucleus is mottled, suggesting patches of dark matter like the two dust bands encircling M-31.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.



Sketch by David J. Eicher

One of the finest large open clusters in the northern sky is **NGC-752**. This group spans 45′ — 1½ Moon diameters — and contains over 70 stars, the brightest of which shine at eighth magnitude. With binoculars or a finder telescope, look about 5° south and slightly west of Gamma. You'll see a loose, scattered grouping of the several dozen brightest stars in the cluster. Rich-field telescopes between 4- and 8-inches in aperture provide the nicest views, showing over 70 stars.

An unusual planetary nebula is **NGC-7662**. It lies ½° southwest of the fifth-magnitude star 13 Andromedae. NGC-7662 is one of the double-ringed planetaries, which display a bright, well-defined ring of gas encapsulated by a much larger, dimmer, and hazier envelope. The problem in observing this nebula is its small size of 32″ x 28″. It shines at eighth magnitude, but you'll need great magnification and clear skies to see more than just a fuzzy "star." In 3- and 4-inch scopes, NGC-7662 appears as a bluish-green point source; it is similar to its stellar neighbors except for the contrasting color. Eight-inch telescopes at 300x, seeing and transparency permitting, show NGC-7662 as an elliptical ring of light with a dark center. An 8-incher doesn't show the outer nebulosity or the dim 13th magnitude central star, but larger scopes may.

Gamma (γ) Andromedae is a favorite double star for owners of small telescopes. Also known as Almach, this star's colorful components are second only to those of Albireo in Cygnus. The magnitude 2.2 primary is golden-yellow or slightly orange, while the 5.1 magnitude secondary is a striking greenish-blue. The fainter star lies about 10″ away from the primary, in position angle 63°. Virtually any telescope used at medium powers will show both of these stars, with an inky blackness of space between. Keep in mind that this small dark gap represents over 74 billion miles! The primary is itself a double, but the separation of its two stars is only 0.3″. The brightest member of Gamma is a spectroscopic double, making this a system with four stars.

Typical of the long period variables, **R Andromedae** has a period of 409 days during which it fluctuates between magnitudes 5.3 and 15.1. R Andromedae is easily found near a bright triangle formed by the stars Theta (θ), Rho (ϱ), and Sigma (σ) Andromedae. If you have keen eyesight and a dark sky, try to record when R Andromedae appears and disappears without optical aid. You can also conveniently follow its brightness changes with a small telescope, which should show the star during most of its cycle.

There are three great spirals in the Local Group of galaxies: the Milky Way, M-31, and the large face-on galaxy **M-33** (NGC-598) in Triangulum. At a distance of 1.1 megaparsecs, M-33 is the closest face-on galaxy but has a reputation for being very elusive. Its total magnitude is 5.7, yet on poor viewing nights, small telescopes will barely show its core. This is because its dimensions of 62′ x 39′ and face-on orientation give the galaxy's spiral arms a surface brightness of only 14.0 magnitudes per square arc-minute. Dark skies coupled with large apertures and low f/ratios, however, show detail in M-33's arms: knotty patches of dark nebulosity, a tiny stellar nucleus, a faintly glowing spiral pattern, knots of bright material tucked in the arms, and the bright starcloud NGC-206. This feature lies 10′ northeast of the starlike core, and contains enough material to make a small galaxy of its own!

NGC-672 is a bright barred spiral in Triangulum. It measures 4.5′ x 1.7′ and glows at 11.6 magnitude, making it an easy mark for a 4-inch telescope, even at low power. A 10-inch scope at high power shows an oval halo of faint nebulosity with a bright, distinctly mottled inner core. Larger telescopes under dark skies may show details in this galaxy, which is often overlooked because of its large, bright neighbor M-33.

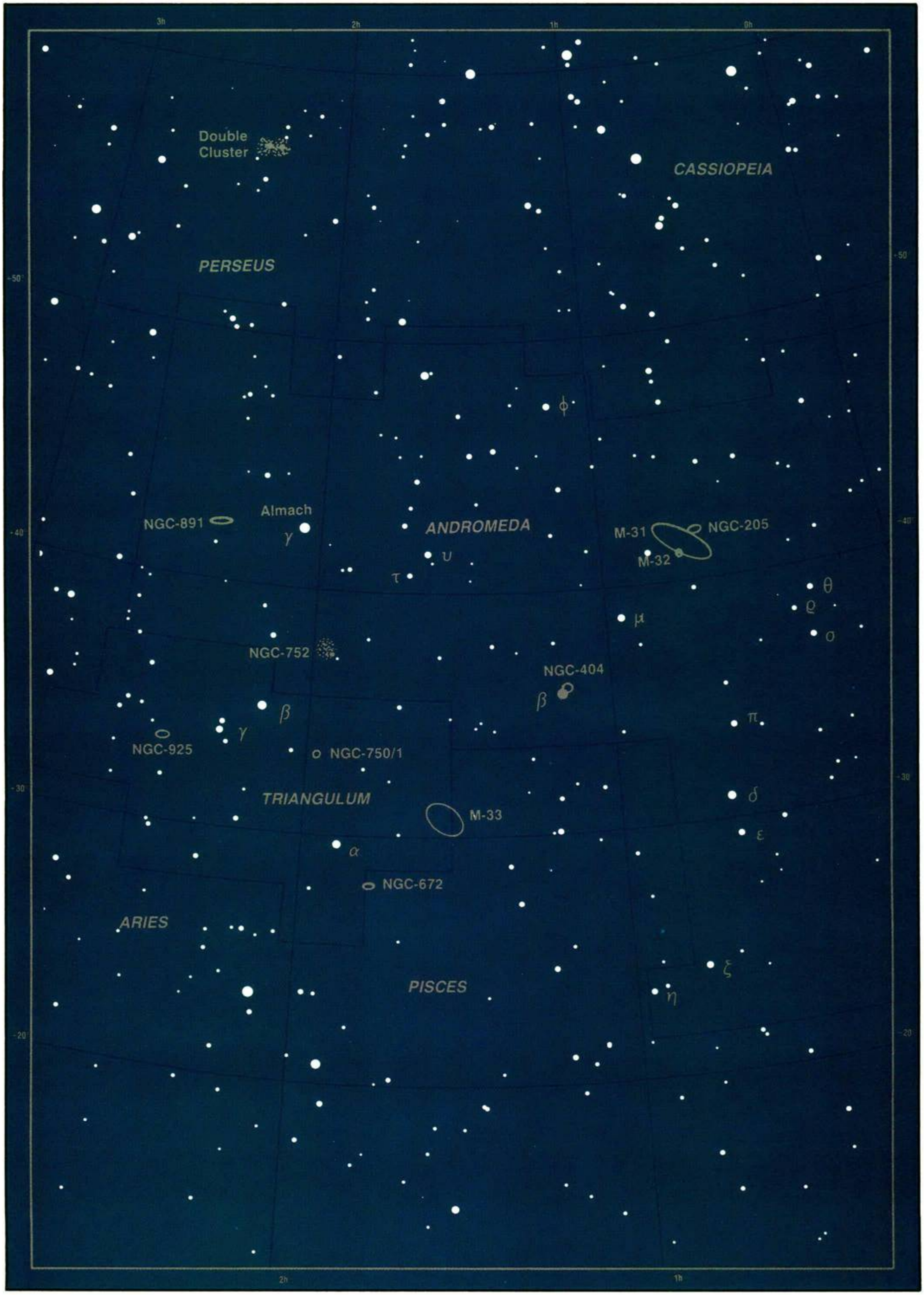
Far more challenging than either M-33 or NGC-672 is a small double galaxy named **NGC-750/1**. This object consists of two faint ellipticals, NGC-750 and NGC-751. They are separated by only 24″, so spotting them is a difficult task. NGC-750 shines at magnitude 13.0 and measures 24″ x 18″, while NGC-751 is a 13.8 magnitude galaxy covering 12″ of sky. With small telescopes, these galaxies appear as two fuzzy "stars" that almost touch each other. A 17.5-inch reflector provides enough light-gathering power to see the galaxies as side-by-side nebular balls of pale grey light.

A final galaxy in Triangulum is **NGC-925** — a large, faint Sb-type spiral. This galaxy measures 9.4′ x 4.0′ and is steeply inclined to our line-of-sight, which keeps its surface brightness fairly high. A 4-inch scope shows it as an elliptical, ghostly patch of milky light. A 10-incher shows some mottling about the nucleus, but doesn't reveal much more detail. Reflectors in the 16-inch to 20-inch range show some dusty structure surrounding the galaxy's hub, and a large outer envelope of even, faint light representing millions of unresolved stars.

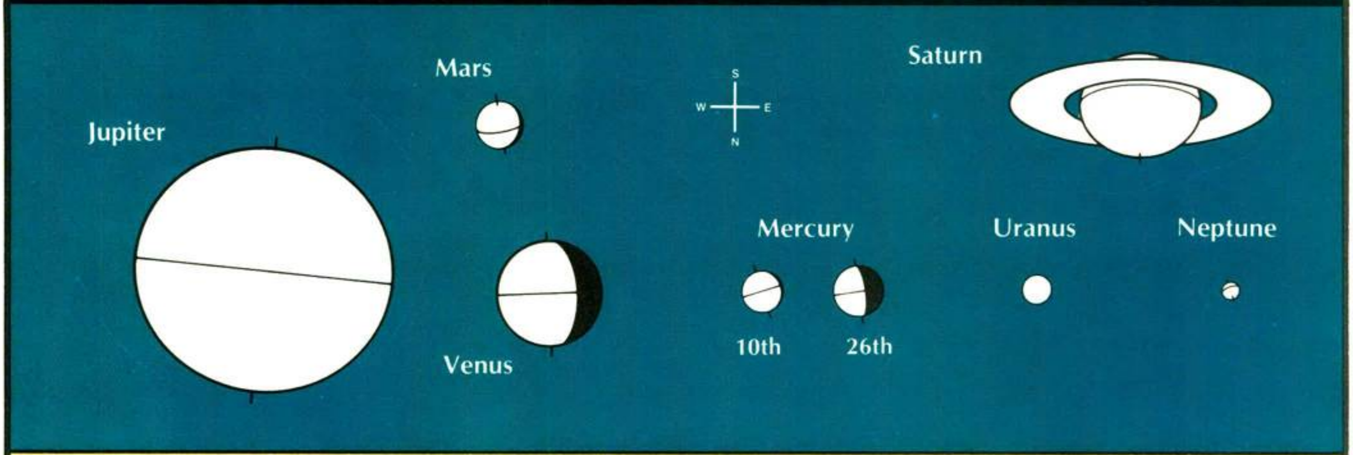
Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
R And		LPV	0h 24.0m	+38°34′	5.3↔15.1	409d	
NGC-205		0	0h 40.3m	+41°41′	8.0	17.4′x9.8′	E5pec
NGC-221	M-32	0	0h 42.7m	+40°52′	8.2	7.6′x5.8′	E2
NGC-224	M-31	§	0h 42.7m	+41°16′	3.5	177.8′x63.1′	Sb
NGC-404		0L	1h 09.4m	+35°43′	11.9	1.3′x1.3′	SO3
NGC-598	M-33	§	1h 33.9m	+30°39′	5.7	61.7′x38.9′	Sc(s)
NGC-672		§B	1h 47.8m	+27°26′	11.6	4.5′x1.7′	SBc
NGC-750/1		0	1h 57.5m	+33°13′	13.0,13.8	24″x18″,12″	EO
NGC-752		⊙	1h 57.8m	+37°41′	6.5	45′	
Gamma (γ) And		★^{2}	2h 03.8m	+42°20′	2.1,5.1	10″	
NGC-891		§	2h 22.4m	+42°21′	12.2	12.0′x1.0′	Sb
NGC-925		§B	2h 27.3m	+33°35′	12.0	9.4′x4.0′	SBc(s)
NGC-7640		§B	23h 22.1m	+40°51′	12.5	9.0′x1.0′	SBc(s)
NGC-7662		■	23h 25.8m	+42°28′	8.6	17″x14″	

H = Hubble classification type for galaxies

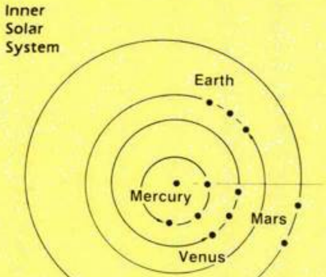
★^{2}	*Double Star*
LPV	*Long Period Variable*
⊙	*Open Cluster*
■	*Planetary Nebula*
§	*Spiral Galaxy*
§B	*Barred Spiral Galaxy*
0	*Elliptical Galaxy*
0L	*Lenticular Galaxy*

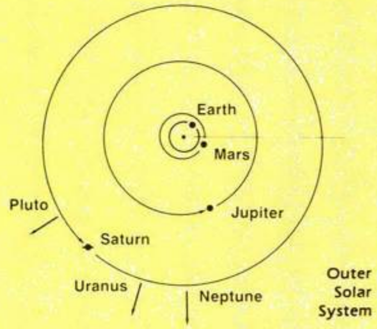

3h
2h
1h
0h
+50°
+40°
+30°
+20°
Double Cluster
CASSIOPEIA
PERSEUS
ϕ
NGC-891
Almach
γ
ANDROMEDA
M-31
NGC-205
M-32
υ
τ
θ
ϱ
μ
σ
NGC-752
NGC-404
β
β
π
NGC-925
γ
NGC-750/1
TRIANGULUM
M-33
δ
ε
α
NGC-672
ARIES
ξ
PISCES
η
2h
1h

Planetary Data November 1984


Mars
Saturn
Jupiter
S
W
E
N
Mercury
Uranus
Neptune
10th
26th
Venus

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.3′	—	0.99	—	—	218°45.4′	14h 26.3m	−14°29.2′
		15	−26.8	32.4′	—	0.99	—	—	232°48.7′	15h 22.5m	−18°31.7′
		30	−26.8	32.5′	—	0.99	—	—	247°58.4′	16h 25.7m	−21°40.4′
Mercury	☿	1	−0.5	4.9″	94%	1.38	0.47	260°36.0′	231°19.2′	15h 17.0m	−19°30.4′
		15	−0.4	5.5″	83%	1.22	0.43	301°19.0′	251°35.9′	16h 42.0m	−24°38.6′
		30	−0.2	7.3″	50%	0.92	0.36	359°12.4′	268°21.4′	17h 56.6m	−25°29.2′
Venus	♀	1	−4.0	13.3″	80%	1.25	0.73	306°46.9′	253°48.6′	16h 52.0m	−24°03.1′
		15	−4.0	14.3″	77%	1.63	0.73	328°56.1′	270°43.8′	18h 06.3m	−25°27.5′
		30	−4.1	15.7″	72%	1.07	0.73	352°43.7′	288°41.0′	19h 25.4m	−24°19.1′
Mars	♂	15	0.6	6.5″	88%	1.43	1.38	340°32.4′	298°57.7′	20h 08.8m	−21°54.2′
Jupiter	♃	15	−2.0	34.1″	100%	5.77	5.17	289°35.0′	280°51.9′	18h 50.3m	−23°07.7′
Saturn	♄	15	0.5	15.2″	100%	10.89	9.90	229°11.9′	229°02.3′	15h 11.4m	−15°42.4′
Uranus	⛢	15	5.7	3.5″	100%	19.97	19.04	253°33.4′	252°06.7′	16h 45.2m	−22°19.5′
Neptune	♆	15	8.0	2.2″	100%	31.04	30.26	270°55.4′	269°22.4′	18h 00.0m	−22°19.0′
Pluto	♇	15	13.8	0.1″	100%	30.68	29.80	212°13.7′	212°23.0′	14h 25.6m	2°47.0′

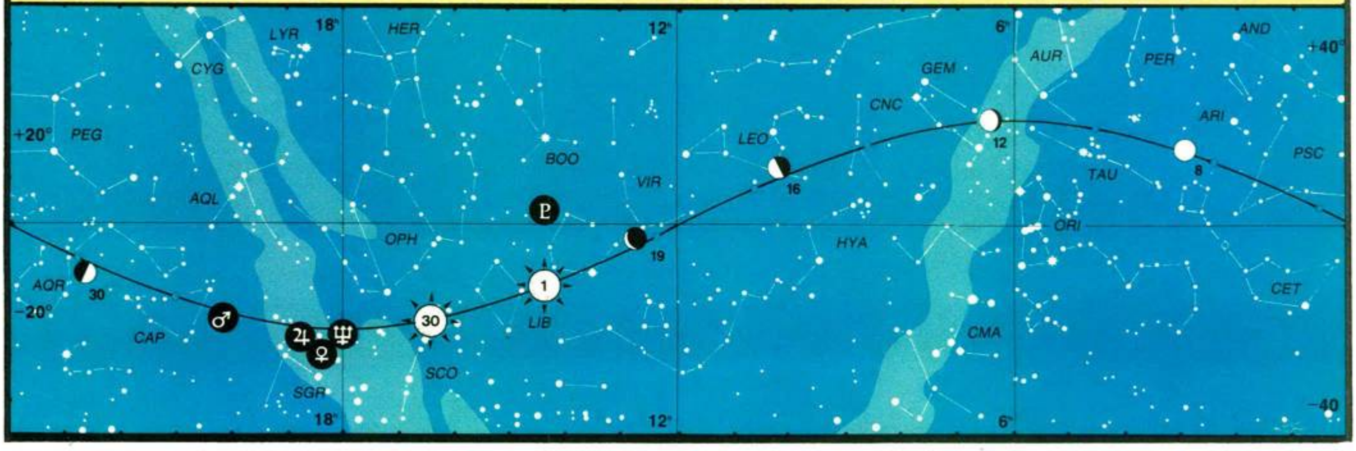

Inner
Solar
System
Earth
Mercury
Mars
Venus


Earth
Mars
Pluto
Jupiter
Saturn
Uranus
Neptune
Outer
Solar
System

Moon Data

Full Moon	Nov. 8 at 17:43
Last Quarter	Nov. 16 at 6:59
New Moon	Nov. 22 at 22:57
First Quarter	Nov. 30 at 8:00
Full Moon	Dec. 8 at 10:53
Last Quarter	Dec. 15 at 15:25

Apogee: Nov. 4 at 22:39.....405,692 km.
Perigee: Nov. 20 at 20:52.....362,825 km.


LYR
18h
HER
12h
6h
AUR
AND
+40°
CYG
GEM
PER
CNC
ARI
+20°
PEG
LEO
12
PSC
BOO
8
TAU
AQL
VIR
16
ORI
OPH
19
HYA
AQR
30
1
CET
−20°
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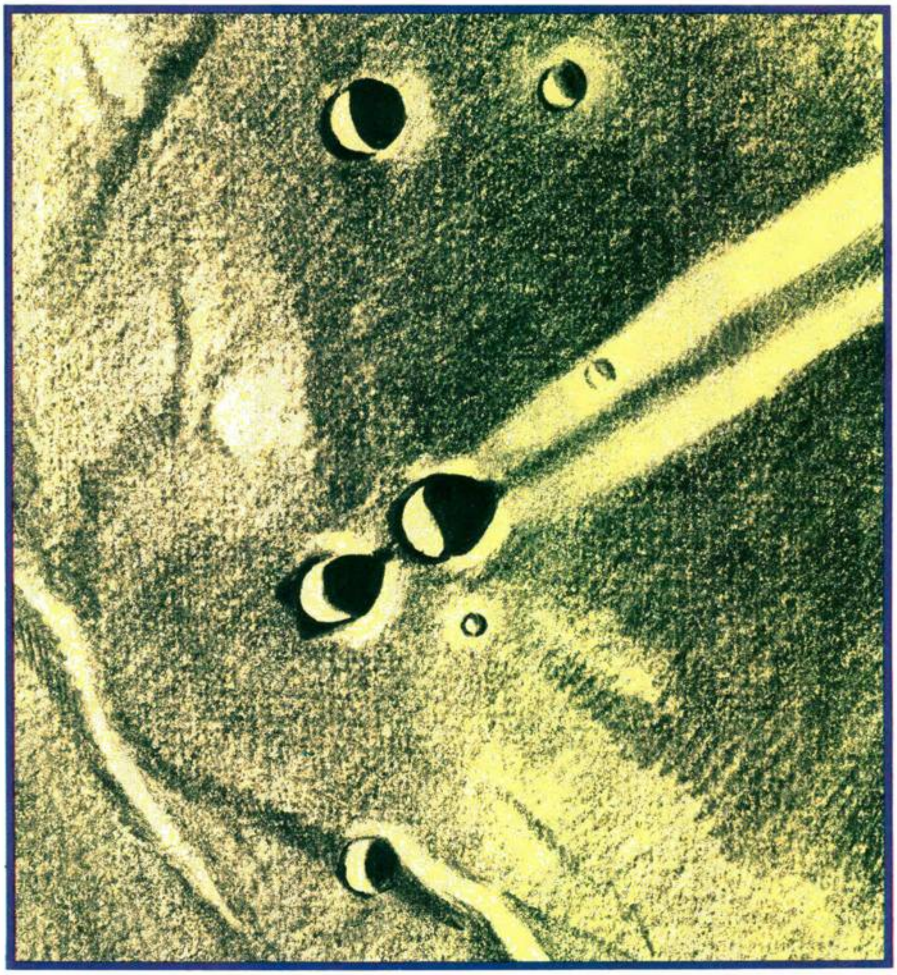
SGR
18h
12h
6h
−40



The twin craters Messier (left) and Messier A form a curious pair on the western expanses of Mare Fecunditatis. The double "tail" extending to the right is probably a result of the low-angle glancing impact that created this feature. Mark Daniels used an 8-inch Newtonian at 300x to create this drawing.

Mercury

The innermost planet, Mercury, reaches greatest eastern elongation in the evening sky on November 25th, but its visibility during this apparition is quite poor. It will be too close to the Sun to be seen until around the 15th, and at maximum elevation on the 28th, Mercury will be scarcely 4° high, 45 minutes after sundown. A slim crescent Moon will lie to the left of Mercury on the 24th, making it easier to spot.

In a telescope, Mercury's disk will vary from 5.5" of arc across on the 15th to 8.6" by the time it vanishes from view in early December. (Inferior conjunction is on December 14th.) During this time, it will display lunar-like phases that vary from gibbous on the 15th, through half-lit by the 30th, to crescent in early December.

Venus

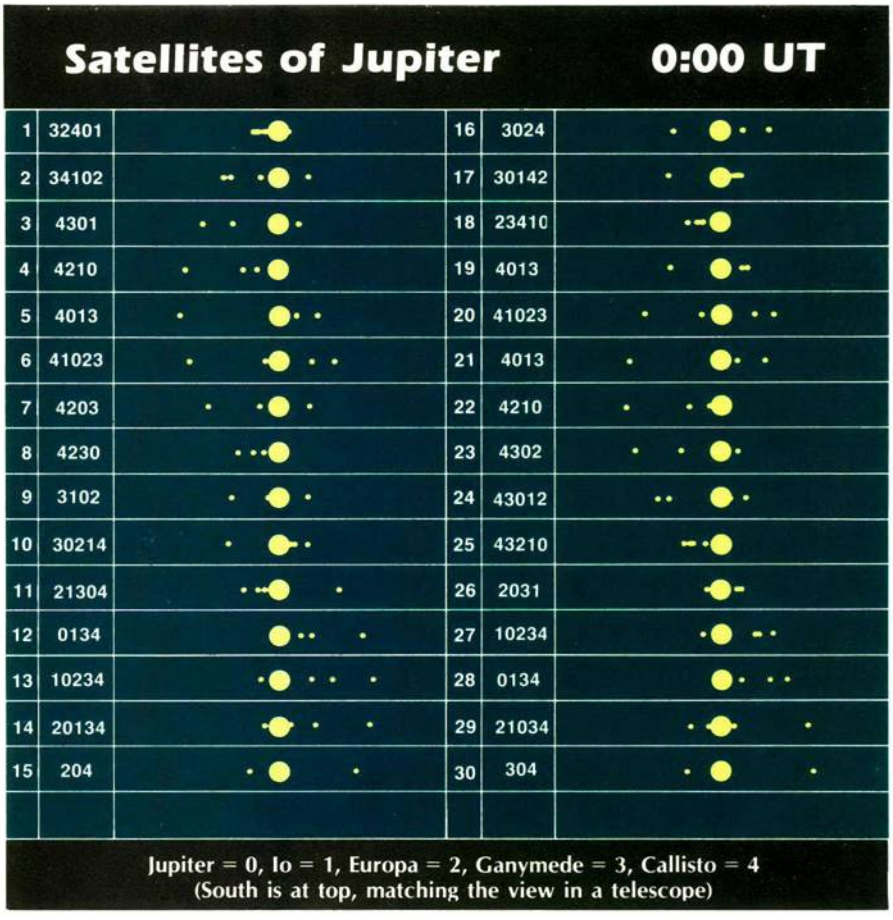
A prominent feature of the evening sky, Venus is slowing its southward march along the horizon. Over the next three months, it will double its present elevation, so visibility of this planet should improve substantially by late winter.

On November 19th around 1:35 UT, Venus will pass very close to Lambda (λ) Sagittarii — the 2.8 magnitude star at the top of the Teapot's "lid." As seen from parts of Alaska and British Columbia, Venus will actually occult this star; viewed from the western U.S., the planet will pass one or two seconds of arc away from it. Elsewhere in North America, Venus and Lambda will appear closely paired. Many telescopic observers will see the star disappear when it is near the bright limb of the planet, due to the irradiated glare of sunlight reflecting from Venus' cloudtops.

Moon

Viewers in New Guinea and the South Pacific will witness a total eclipse of the Sun on November 22nd and 23rd. The path of totality begins at sunrise on the 23rd in the Banda Sea east of New Guinea. It will cross that island and head southeast through the western South Pacific, passing 500 kilometers north of New Zealand. After crossing the International Date Line around latitude 35° south, the eclipse will head eastward over the South Pacific toward South America where it ends, still at sea, near longitude 90° west and latitude 35° south at sunset on the 22nd.

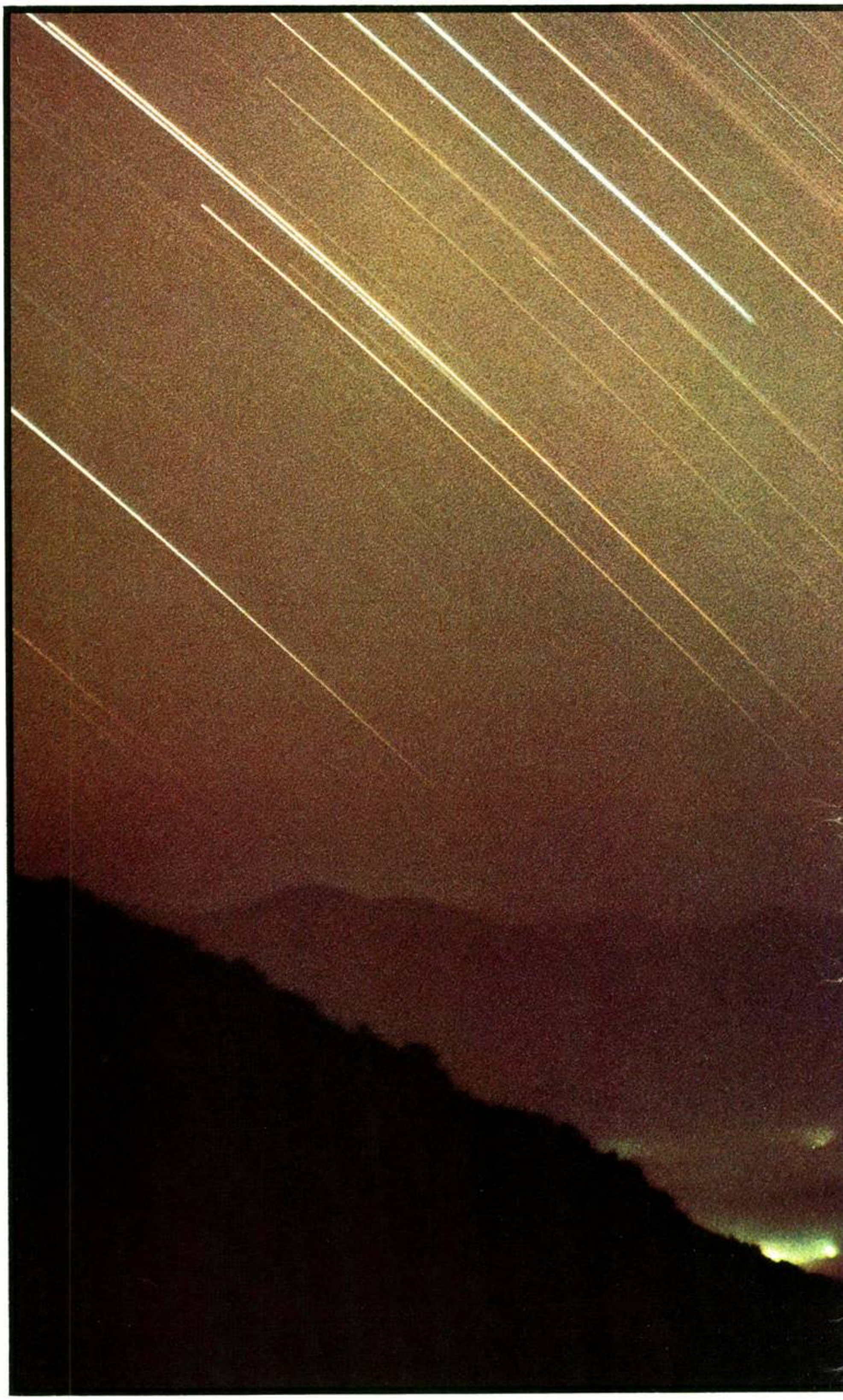
On November 8th (two weeks before the solar eclipse) there will be a penumbral eclipse of the Moon lasting from 15:39 to 20:12 UT, but the event — producing only a slight darkening of the Moon's northern limb — won't be visible



Satellites of Jupiter 0:00 UT

1	32401	16	3024
2	34102	17	30142
3	4301	18	23410
4	4210	19	4013
5	4013	20	41023
6	41023	21	4013
7	4203	22	4210
8	4230	23	4302
9	3102	24	43012
10	30214	25	43210
11	21304	26	2031
12	0134	27	10234
13	10234	28	0134
14	20134	29	21034
15	204	30	304

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)



A 30-minute exposure from the top of Brasstown Bald Mountain in Georgia caught this bright Perseid during the 1981 shower. This month's "Best Astro-Photo" award goes to Richard Lubrant of Atlanta, who used a 55mm f/1.4 lens and Ektachrome 200 film to take the photo.

from North America.

Mars

With twice Jupiter's elevation in the evening sky, Mars still holds a few attractions for backyard telescopes despite its comparative dimness and small apparent size. Mars now has about half the diameter we saw at opposition in early July; the scanty albedo markings evident then have become even less visible. Often, you are left with an almost featureless tawny dot that swims in your telescope's eyepiece.

But while there isn't too much to see, try to observe Mars as frequently as opportunity allows. Red filters enhance the contrast on surface detail, while blue filters are useful for bringing out transient features (such as clouds and haze) in the martian atmosphere.

Asteroids

1 Ceres (magnitude 6.9) is at opposition on November 12th, north of the star Menkar in the tail of Cetus. At 19:33 UT on the 25th, Ceres will pass 5′ south of the 4.7 magnitude star Lambda (λ) Ceti. Its positions:

10th: 3h 14m 23.1s, 8° 52.4′
20th: 3h 4m 55.5s, 8° 47.6′

Ceres is visible all night long.

2 Pallas (9.6) is moving southeastward in central Aquarius. Its positions:

10th: 22h 26m 15.9s, −9° 16.0′
20th: 22h 30m 15.5s, −10° 2.6′

Pallas sets around midnight on the 15th.

3 Juno (10.6) is moving southeastward out of Leo into Virgo. Its positions:

10th: 11h 42m 16.6s, −0° 32.7′
20th: 11h 55m 27.4s, −1° 35.8′

Juno rises around 2 a.m. local time in mid-November.

4 Vesta (8.1) is in Virgo, headed southeast on a course roughly parallel to that of Juno. Its positions:

10th: 12h 8m 47.1s, 4° 24.3
20th: 12h 26m 26.6s, 2° 56.7′

Vesta rises around 2 a.m. on the 15th.

For convenience in plotting their positions on a star atlas, all asteroid coordinates are for the epoch 2000.0.

Jupiter

Jupiter has a meeting with Venus in the evening sky during late November. It is also being encroached upon by twilight. and won't remain a telescopically interesting sight much longer.

Saturn

Saturn is in conjunction with the Sun on November 11th. It will reappear very low in the morning sky by the end of November, but its visibility will be so poor as to show very little in your telescope until December or January.

Uranus

Uranus disappears into the evening twilight this month and reaches conjunction with the Sun on December 5th.

Neptune

Neptune is also about to vanish from our telescopic sights. In conjunction on December 22nd, it is very low in the southwestern sky during November evenings, and its 2.2″ disk will be very difficult to discern.

Meteors

This month's biggest showers are the Taurids on the 5th, the Andromedids on the 14th, and the Leonids on the 17th.

The Taurids' peak activity comes three days before the Full Moon. These are actually the *southern* Taurids. There is also a northern stream but it has a different radiant, a slightly later peak date, and much fewer numbers. The Taurids stem

from Comet Encke and appear to radiate from a location near the Pleiades. They are bright and fireballs are relatively common. From a dark-sky site, you can expect about 15 meteors an hour.

The Andromedids peak two days before the Last Quarter; their radiant lies near Gamma (γ) Andromedae. The parent comet is Biela's — hence their alternate name, the Bielids. This shower was strong around the turn of the century, but has now become weak and diffused. The meteors are generally faint although some display colors.

The Leonids are a well-known stream, but most years produce only a so-so shower. Their fame results from the displays (normally once every 33 years) when the parent comet (Tempel-Tuttle) returns, bringing with it truly awesome numbers of Leonids. (The next scheduled return is 1998.) As the name suggests, the radiant lies in Leo, near the Sickle. The date of maximum activity this year is one day after the Last Quarter Moon, so the relatively small number of Leonids that are visible will be further diminished by moonlight. (Be sure to see this month's Photography in Astronomy on photographing meteor showers.)

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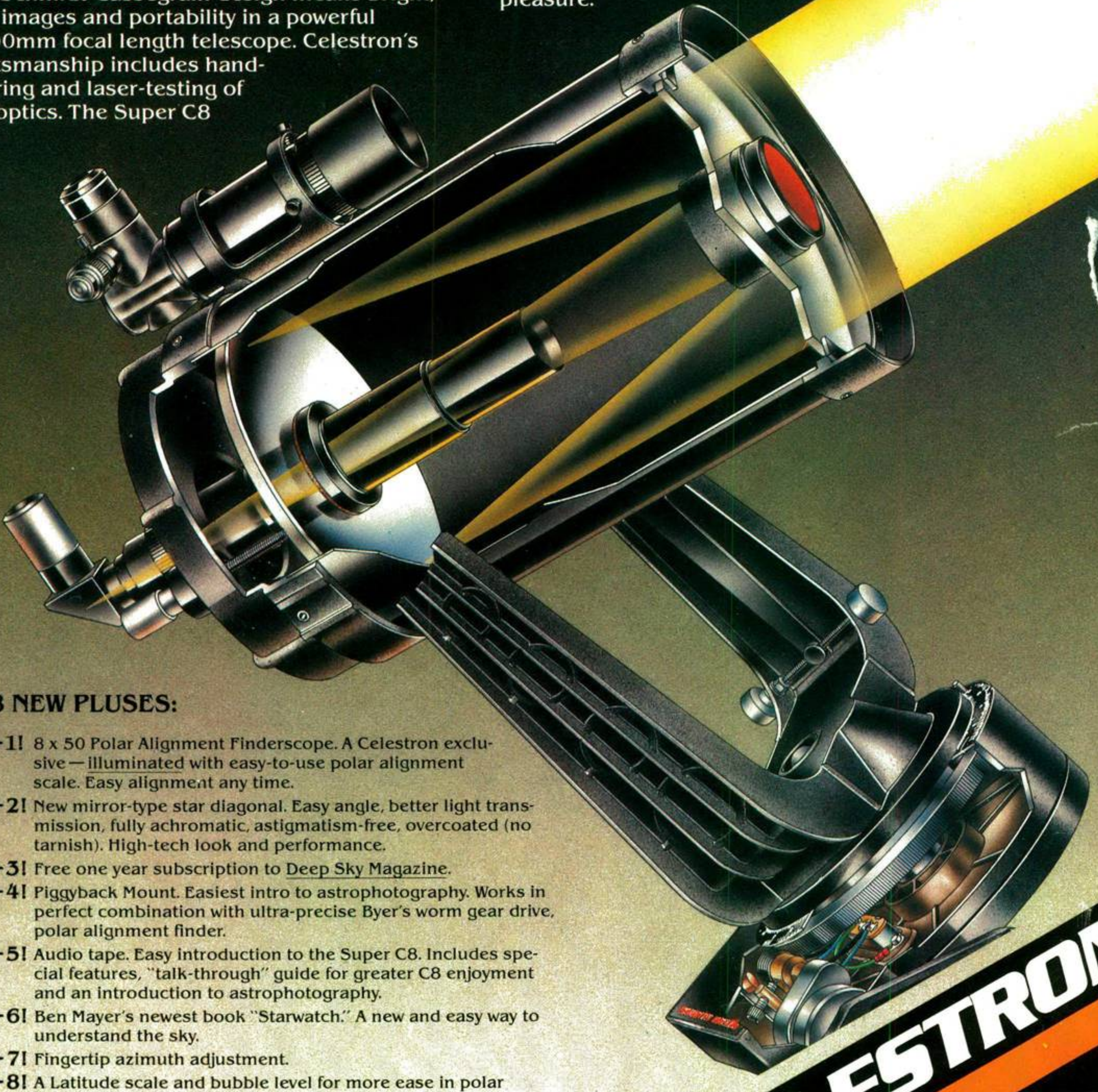
Only Celestron combines state-of- the-art technical advances with a vast array of practical advantages.

Celestron's world-renowned optical design and Celestron Certified Diffraction-Limited Optics assure you of the best optical value available today. The Schmidt-Cassegrain design means bright, f/10 images and portability in a powerful 2,000mm focal length telescope. Celestron's craftsmanship includes hand-figuring and laser-testing of the optics. The Super C8 features a superb Byer's worm gear drive, the most accurate clock drive available today, a patented (pending) design built with special Swiss machine tools.

But even the finest instrument must be used and enjoyed. So we've taken the mystique out of astronomy.

Owning a Celestron Super C8 Plus is exciting. Now we've added 8 new pluses for even greater pleasure.



8 NEW PLUSES:

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+3! Free one year subscription to Deep Sky Magazine.

+4! Piggyback Mount. Easiest intro to astrophotography. Works in perfect combination with ultra-precise Byer's worm gear drive, polar alignment finder.

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+7! Fingertip azimuth adjustment.

+8! A Latitude scale and bubble level for more ease in polar alignment.

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